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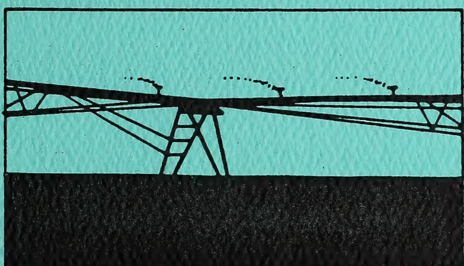

Applied Research Report
1993 - 1994

Alberta
AGRICULTURE, FOOD AND
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1993-94

APPLIED RESEARCH REPORT

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

ALBERTA AGRICULTURE, FOOD AND RURAL DEVELOPMENT

March, 1994

PREFACE

The Irrigation and Resource Management Division Annual Applied Research Report is a collection of progress and final research reports. The research is carried out by staff members of the Division and private consultants retained under contract. Research projects vary from detailed tests to field surveys; from irrigation to conservation topics.

The reports are limited in length and summarize the highlights. The detailed data and information is available from the individual researchers. The reports have been grouped according to subject matter. The authors are responsible for the contents of the report.

Copying of the material is permitted provided credit is given to the researcher(s) and the data and interpretations are not altered.

ACKNOWLEDGEMENTS

I would like to thank the staff members who carried out the research and prepared the reports in this 1993-94 edition of the Applied Research Report of the Irrigation and Resource Management Division. I acknowledge the great effort to plan and carry out these projects. I also appreciate the encouragement and support provided by their supervisors. On behalf of all, I thank the farmers, the Irrigation Districts, Agriculture Research Associations, Agriculture Organizations, and Agricultural Service Boards for their cooperation.

In particular, I thank Bev Danyluk for reformatting the papers, and Hank VanderPluym and Barb Shackel for compiling and printing the Report.

Brian L. Colgan
Director
Irrigation & Resource Management Division

IRRIGATION AND RESOURCE MANAGEMENT DIVISION

APPLIED RESEARCH REPORT - 1993-94

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IREP RECLAMATION EFFECTIVENESS STUDY

K. M. Riddell and D. R. Bennett[1]

INTRODUCTION

The Irrigation Rehabilitation and Expansion (IREP) Reclamation Effectiveness Study was initiated in 1988 to examine the success of various seepage control measures in reclaiming seepage-affected land. The study responds to concerns raised in the Coopers and Lybrand report (1987) about the lack of documentation of reclamation in the irrigation districts. Reclamation is achieved by lowering the water table and reducing soil profile salinity to levels which will not affect crop growth.

Previous research on post-canal rehabilitation water table and salinity levels next to canals in the Lethbridge Northern, Raymond, St. Mary River and Taber Irrigation Districts found that elimination of seepage did not guarantee soil reclamation (Bennett 1990). Water table and salinity levels next to canals were also influenced by surface drainage, local and regional groundwater flow, internal drainage of the soil and geologic materials (Bennett 1990; Millette et al. 1992). Installation of subsurface or surface drainage, changes in irrigation practices and/or control of groundwater recharge may be needed, in addition to canal rehabilitation, to achieve reclamation.

The objective of this study was to document soil salinity and water table conditions adjacent to canals prior to and after the installation of seepage controls, and to determine the extent of land reclamation.

METHODS

Site selection was limited to saline/waterlogged areas adjacent to canals scheduled for rehabilitation in the fall of 1989. Site selection considerations included: severity and extent of saline/waterlogged soils, rehabilitation method, type of irrigation system, farmer cooperation and ease of access. Six sites located within four irrigation districts in southern Alberta were selected (Figure 1). A wide range of canal rehabilitation methods and irrigation systems were selected (Table 1), as well as a wide range of soil landscapes (Table 2).

Table 1. Name of canal, rehabilitation method and type of irrigation system for each ICW reclamation effectiveness site.

Site #	Irrigation District	Canal	Method of Seepage Control	Type of Irrigation System
1	EID	Lateral 14-03 Bow Slope	Polylining	Flood
2	EID	Lateral 14-03 Bow Slope	Polylining	Pivot
3	LNID	Monarch Branch	Grid Drainage	Wheel move
4	BRID	Lateral K-5	Polylining	Flood
5	TID	East Horsefly Main	Polylining	Wheel move
6	TID	East Horsefly Main	Polylining	Pivot

[1]Land Evaluation and Reclamation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.

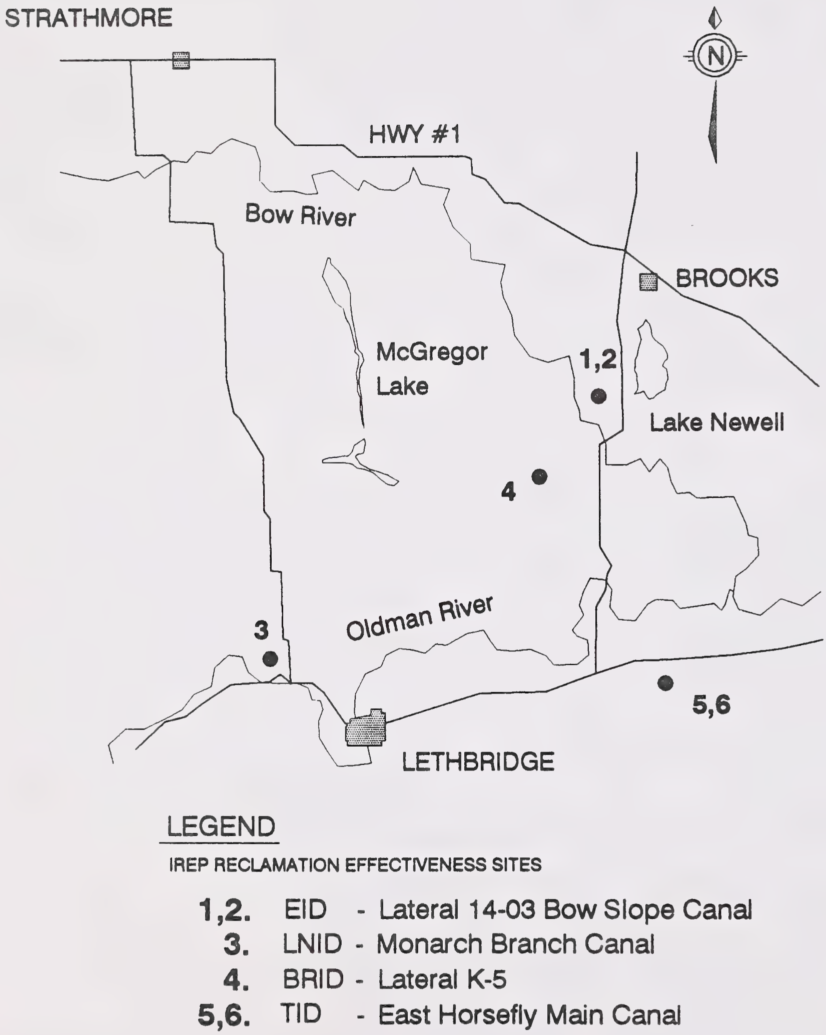

Figure 1. Location of IREP reclamation effectiveness sites.

Table 2. Soil landscape features at IREP reclamation effectiveness sites established in 1989

Site #	Surface Expression	Topography (% Slope)	Parent Material	Soil Profile(s)
1	level	0.5 - 2.5	sandy loam fluvial (0.8-1.0 m thick) over clay loam till	Carbonated Brown Chernozemic
2	undulating	2.0 - 5.0	discontinuous sandy loam fluvial (0-0.5 m thick) over clay loam till	Saline-Carbonated Brown Chernozemic and Solonetzic Humic Gleysol
3	inclined	2.0 - 5.0	silty clay loam lacustrine (2-3 m thick) over clay loam till	Saline-Carbonated Dark Brown Chernozemic
4	level	0.5 - 2.5	clay loam till with discontinuous pockets of sandy loam fluvial (1-2 m thick) over till	Saline-Carbonated Brown Chernozemic
5	undulating	2.0 - 5.0	clay loam till	Saline-Carbonated Brown Chernozemic
6	undulating	2.0 - 5.0	clay loam till	Saline-Carbonated Brown Chernozemic

EM-38 salinity surveys, using a 50 x 50 m grid, were conducted at each site in late April. Readings were taken with the instrument in the vertical mode. Temperature-corrected EM-38 data were subsequently converted to paste-equivalent electrical conductivity (EC_e) values (McKenzie et al. 1989). Grid EC_e values were then contoured using "Surfer" computer software to produce a 1:1875 scale salinity map for each site.

Two to six, 20 x 20 m, plots were then selected at each site based on the results of the EM-38 survey. Plot corners were referenced to permanent benchmarks at each site. Soil samples were taken at the corners and centre of each plot in the fall of 1989, 1991 and 1993 using a 100-mm core barrel. Sampling was done within a 1 m diameter circle of each sampling location. Soil samples were taken in 0.30 m depth increments from ground surface to a depth of 1.2 m. Soil samples were analyzed for pH, electrical conductivity (EC) and sodium adsorption ratio (SAR) of the saturation extract (Rhoades 1982).

Water-table wells (WTW's) were installed to a depth of 4.5 m in the centre of each plot at each site in May, 1989. Drilling was done using continuous flight augers. Water-table wells were constructed of 37 mm (ID) PVC pipe, slotted to within 0.15 m of ground surface and backfilled with cuttings to the top of the slotted pipe. A bentonite plug was installed from a depth of 0.15 m to ground surface.

Water levels were read every two weeks during the irrigation season, weekly during canal turnon and shutdown events, and monthly during the winter. Water levels were monitored from May, 1989 until March, 1992. A datalogger connected to an automatic water level recorder and a tipping bucket rain gauge was installed over a single WTW at each site. This allowed continuous monitoring of water-table fluctuations in response to irrigation and precipitation events.

Statistical analyses on EC and SAR data consisted of analysis of variance using a split-plot design (split by time) to test for differences between years for each sampling depth (Gomez and Gomez 1984). Yearly averages were compared using a Tukey test, if analysis of variance showed differences between years to be significant ($p \leq 0.05$).

RESULTS

Growing season (May 1 to Oct. 31) precipitation (rainfall + irrigation)

Growing season precipitation records from 1989 to 1993 showed a steady increase in rainfall between 1990 and 1993 at all sites (Table 3). Increased fall (Sept. and Oct.) rainfall occurred at all sites in 1992 and 1993.

Conversely, irrigation amounts declined between 1990 and 1993 at Sites 2 and 3 (Table 3). Irrigation amounts increased between 1990 and 1992 at Site 6 (Table 3).

Soil EC and SAR

Mean EC and SAR levels in the upper 0.6 m portion of the soil profile generally decreased in 1993, as compared to levels observed in 1989 and 1991, at all sites (Figures 2 and 3). Comparison among years of annual mean values of soil EC and SAR at each depth showed significant reductions in EC and SAR in 1993 at the 0-0.6 m depth at Sites 3 and 6 (Figures 2 and 3).

Average post-canal rehabilitation water-table depths

Average post-canal rehabilitation water-table depths were greater than 1.5 m below ground at Sites 3 and 6 (Table 4). Average post-canal rehabilitation water-table depths were less than 1.5 m below ground at Sites 1, 2, 4 and 5 (Table 4).

Table 4. Average post-canal rehabilitation water-table depths of IREP reclamation effectiveness sites

Site #	Average Post-Canal Rehabilitation Water-Table Depth (m below ground)
1	1.3
2	1.0
3	1.6
4	1.0
5	1.0
6	3.5

DISCUSSION

Reduced EC and SAR levels in the upper soil profile (0-0.6 m) in 1993 at all sites were attributed to leaching caused by favourable rains in 1992 and 1993. Fall rains and/or irrigation are very important for leaching salts in western Canada (Millette 1989; Hogg and Tollefson 1992).

Significant reductions in soil EC and SAR in 1993 were only recorded at Sites 3 and 6 where the average post-canal rehabilitation water-table depth was below 1.5 m. Previous research in southern Alberta has shown that the critical water-table depth required to prevent

soil salinization ranges from 1 to 1.5 m, depending on the salinity of groundwater, soil characteristics, local climatic conditions, and type of crop (van Schaik and Milne 1962, 1963; van Schaik and Stevenson 1967).

The largest reduction in soil EC and SAR in the upper soil profile occurred at Site 3 where a subsurface drainage was installed. Subsurface drainage and irrigation management practices that promote net downward movement of water have been successful in achieving some reclamation of saline/waterlogged areas on irrigated land in southern Alberta (Bennett et al. 1982; Buckland et al. 1986; Millette 1989).

Lesser reductions in soil EC and SAR occurred at Sites 1, 2, 4 and 5 where the average post-canal rehabilitation water-table depth remain around 1 m below ground. Persistently shallow water-table depths were attributed to natural groundwater conditions, irrigation management, poor internal drainage characteristics of the soils and surface water at these sites.

CONCLUSIONS

Installation of seepage control measures in 1989, combined with irrigation and favourable rains in 1992 and 1993, has led to significant reductions in EC and SAR levels in the upper soil profile (0-0.6 m) at two out of six sites. Significant reduction in soil EC and SAR levels occurred at Sites 3 and 6, where the average post-rehabilitation water-table depth was below 1.5 m. The largest reduction in soil EC and SAR in the upper profile occurred at Site 3 where a subsurface-drainage system was installed. Lesser reductions in soil EC and SAR occurred at sites where the average post-rehabilitation water-table depth was 1 m below ground.

Table 3. Monthly rainfall and irrigation amounts (mm) for all I.R.E.P. sites established in 1989

Site	Year		May	Jun	Jul	Aug	Sep	Oct	Total	Rain and Irrigation
1	1989	Rain	36	73	6	50	28	0	193	
(Flood)	1990	Rain	70	12	54	15	14	0	165	
	1991	Rain	83	25	49	38	0	0	195	
	1992	Rain	39	92	80	26	68	21	326	
	1993	Rain	26	106	71	89	65	17	374	
2	1989	Rain	36	73	6	50	28	0	193	255
(Pivot)		Irri.[z]	0	0	62	0	0	0	62	
	1990	Rain	70	12	54	15	14	0	165	438
		Irri.	0	27	92	109	45	0	273	
	1991	Rain	83	25	49	38	0	0	195	368
		Irri.	0	63	48	19	31	12	173	
	1992	Rain	39	92	80	26	68	21	326	480
		Irri.	24	3	36	49	27	15	154	
	1993	Rain	26	106	71	89	65	17	374	480
		Irri.	0	82	15	0	0	9	106	
3	1989	Rain	NA[y]	133	30	39	39	7	248	248
(Wheels)		Irri.	NA	NA	NA	NA	NA	NA	NA	
	1990	Rain	85	31	44	17	11	6	194	350
		Irri.	0	0	53	103	0	0	156	
	1991	Rain	59	98	46	66	8	0	277	458
		Irri.	24	136	21	0	0	0	181	
	1992	Rain	24	143	99	123	28	21	438	523
		Irri.	0	85	0	0	0	0	85	
	1993	Rain	49	NA	NA	NA	NA	NA	NA	
		Irri.	0	0	0	0	0	0	0	
4	1989	Rain	NA	70	15	50	24	0	159	
(Flood)	1990	Rain	56	21	36	8	7	5	133	
	1991	Rain	60	92	13	30	1	7	203	
	1992	Rain	39	92	80	26	68	21	326	
	1993	Rain	26	106	71	89	65	17	374	
5	1989	Rain	41	72	54	78	28	0	273	
(Wheels)	1990	Rain	58	0	63	30	0	19	170	
	1991	Rain	60	76	124	22	4	NA	286	
	1992	Rain	8	71	106	68	29	NA	282	
	1993	Rain	18	63	157	40	62	17	357	
6	1989	Rain	41	72	54	78	28	0	273	273
(Pivot)		Irri.	0	0	0	0	0	0	0	
	1990	Rain	58	0	63	30	0	19	170	345
		Irri.	20	63	0	78	0	14	175	
	1991	Rain	60	76	124	22	4	NA	286	470
		Irri.	12	66	20	18	68	NA	184	
	1992	Rain	8	71	106	68	29	NA	282	623
		Irri.	181	69	25	41	25	0	341	
	1993	Rain	18	63	157	40	62	17	357	413
		Irri.	0	38	18	0	0	0	56	

[z] Irri. = Irrigation [y] NA = Information not available

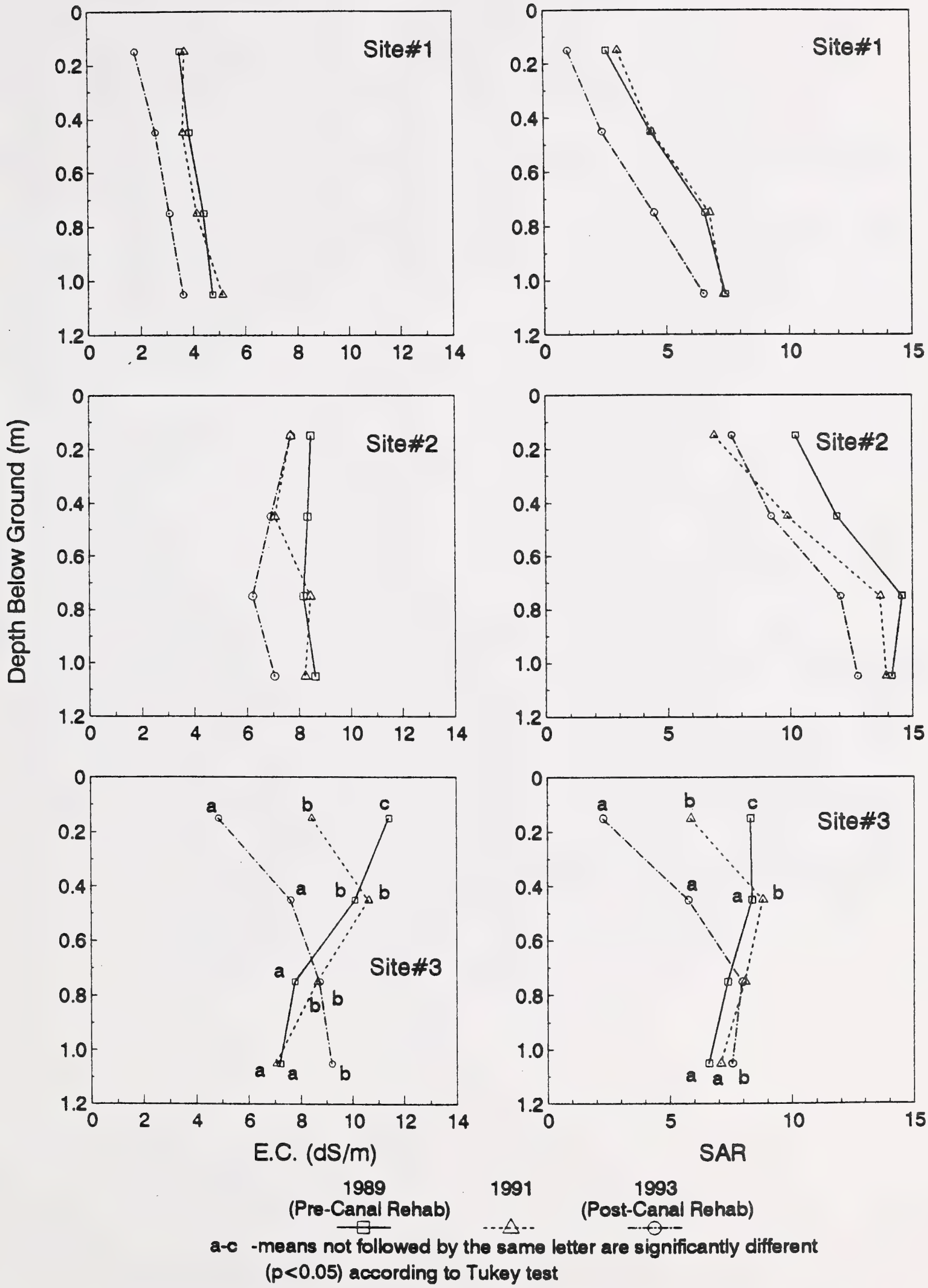

Figure 2. Average soil salinity (E.C.) and sodicity (SAR) levels for IREP reclamation effectiveness Sites 1 to 3.

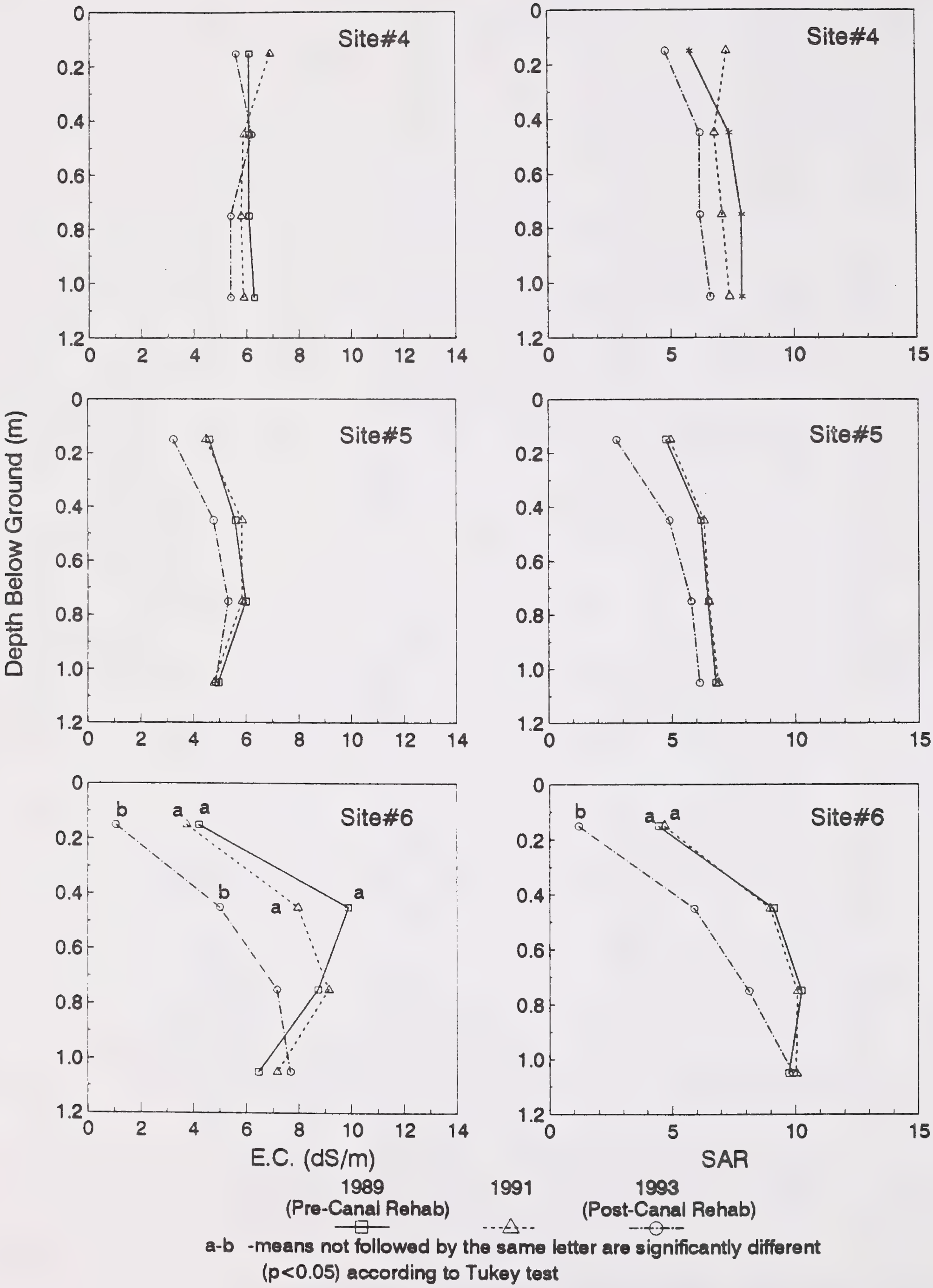

Figure 3. Average soil salinity (E.C.) and sodicity (SAR) levels for IREP reclamation effectiveness Sites 4 to 6.

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SOIL SALINITY AND SODICITY LEVELS ON LANDS IRRIGATED FROM VERDIGRIS LAKE RESERVOIR

K. M. Riddell and G. D. Buckland[2]

INTRODUCTION

Verdigris Lake is a man made reservoir developed in a glacial meltwater channel in southern Alberta. The reservoir covers about 790 ha. and holds 10,000 acre ft. of water.

Approximately 850 ha. of land are irrigated with water from Verdigris Lake which has an electrical conductivity (EC) ranging from 0.3 dS m^{-1} at the inlet (north end) to 1.6 dS m^{-1} at the outlet (south end). Sodium adsorption ratio (SAR) in the water ranges from 0.5 at the inlet to 6 at the outlet.

Electrical conductivity and SAR levels in the water at the inlet end of the Lake fluctuate greatly in response to rainstorms but are generally below safety limits for irrigation water quality (Alberta Agriculture 1983). Water at the lower end and outlet of the reservoir is classified as "Possibly Safe" because EC and SAR levels exceed the safety limits of 1.0 dS m^{-1} and 4.0 as outlined in Alberta Agriculture guidelines (Alberta Agriculture 1983).

Long-term irrigation has the potential to salinize the soil profile if adequate leaching water is not applied or internal drainage is poor. The greater the salt concentration in the irrigation water the greater the risk. In addition, the impact of alternate additions of slightly sodic irrigation water and fresh rainwater on soil structure and infiltration rates is not well understood.

In response to these concerns, the Land Evaluation and Reclamation Branch established three benchmark sites to evaluate the long-term impact on soil quality of irrigation with marginal quality water. This report documents soil EC and SAR levels, from 1990 to 1993 at these benchmark sites.

METHODS

Soil samples were taken from both irrigated and dryland areas at three sites (A, C, and D) in the fall of 1990, 1991, 1992 and 1993 (Figure 1). The sites were selected at the inlet, lower, and outlet locations along Verdigris lake to consider the varying water chemistry in the reservoir. Weekly rainfall and irrigation amounts were recorded at each site over the growing season. All sites were farmed by different landowners and were pivot irrigated.

Four replicates were established for each of the irrigated and dryland treatments at Sites C and D (Figure 2). Three replicates were established for each treatment at Site A because one of the dryland corners adjacent to the pivot was used for corrals. Four soil sampling locations, spaced 25 m apart, were established in each replicate (Figure 2).

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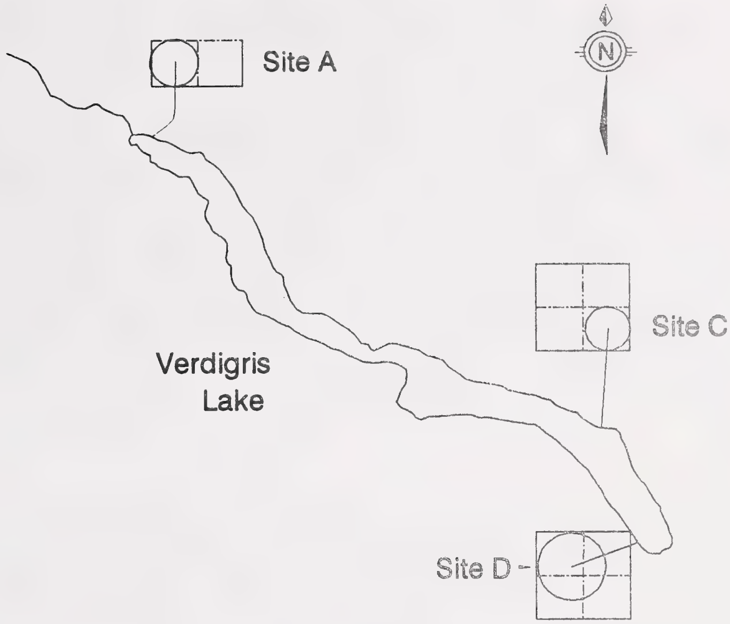

Figure 1. Site location map for Verdigris Lake soil and water quality study.

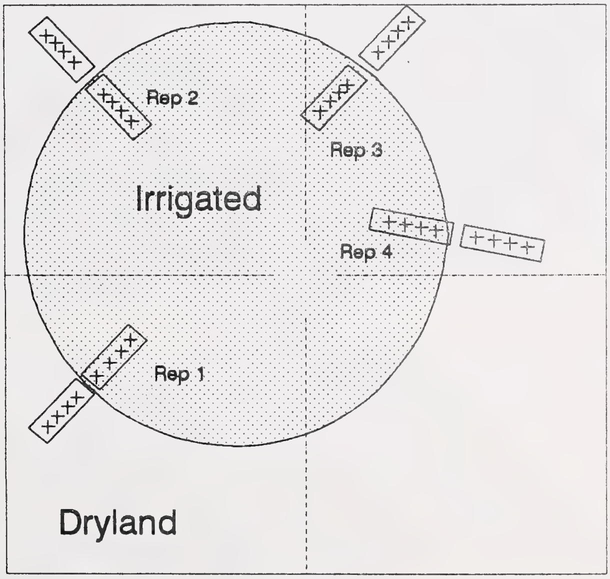

Figure 2. General plan showing replicates and soil sampling locations within replicates at Site D.

Soil profiles were sampled in 15-cm depth increments to a depth of 30 cm and in 30-cm increments from 30 to 120 cm. Soil profiles were described at the time of sampling. Soil samples from the irrigated areas only were analyzed for electrical conductivity (EC) and sodium adsorption ratio (SAR) of saturation extracts (Rhoades 1982).

Statistical analyses were done using a randomized block analysis of variance (ANOVA) on EC and SAR data to determine if time (1990, 1991, 1992 and 1993) effects were significant ($p < 0.05$) for each depth (Gomez and Gomez 1984). Yearly means were compared using Tukey tests if ANOVA showed the time effect to be significant.

RESULTS AND DISCUSSION

Soil Landform

The soil landform at all sites was an undulating till plain with discontinuous veneers of fluvial-lacustrine material overlying the till. Slopes ranged from 2 to 5% in steepness and 50 to 100 m in length. Soil profiles were dominantly (60-70%) Orthic Brown Chernozemic with significant (10-20%) Rego Brown Chernozemic. The dominant soil series at all sites was Masinasin (Kjearsgaard et al. 1984).

Rainfall and Irrigation

The amount of growing season (May 1 - Oct. 31) rainfall at the three sites ranged from 413 to 498 mm in 1993 (Table 1). These levels were well above 249 mm, which is the 1951-1980 growing season average for Brown soil zone (Environment Canada - Atmospheric Environment Service 1982). Rainfall amounts in 1992 ranged from 267 to 282 mm, which would be considered an "average" year. Irrigation amounts ranged from 62 to 156 mm at the three sites in 1993 (Table 1). These levels were lower than in previous years because of the large amount of rainfall in 1993.

Average EC and SAR levels in the irrigation water increased from the lake inlet (Site A) to the mid-Lake (Site C) to the lake outlet (Site D) positions (Table 1). Weighted average SAR levels increased from 1991 to 1993 at Sites A and C and decreased from 1991 to 1993 at Site D.

Table 1. Rain (mm), irrigation (mm) and weighted average irrigation water quality for the 1991 to 1993 growing seasons (May 1-Oct. 31) at Sites A, C, and D.

			Avg. Weighted Irrig. Water Quality	
Site/Year	Rain (mm)	Irrigation (mm)	EC (dS/m)	SAR
1991				
A	ND	182	0.40	1.33
C	ND	289	0.87	3.63
D	209	194	1.39	5.79
1992				
A	267	147	0.43	1.46
C	289	329	0.83	3.56
D	282	350	1.21	5.49
1993				
A	459	62	0.51	1.75
C	498	156	1.20	4.81
D	413	64*	1.31	4.63

* Irrigation was only done on 75 acres in the NW corner of the pivot.

Soil EC and SAR

Soil EC levels in the top 30 cm were lower than previous sampling years at Sites A and D in 1993 (Figure 3). Some decreases were statistically significant, particularly at the shallower depths. These reductions were attributed to higher than normal rainfall, combined with reduced or no irrigation in 1993, which caused leaching.

Soil EC levels in the top 15 cm were higher in 1993 as compared to 1991 and 1992 at Site C (Figure 3). Elevated soil EC levels in the topsoil at Site C may be related to a heavy application (200 kg/ha) of nitrogen fertilizer (ammonium nitrate) just prior to soil sampling. Soil nitrate levels were unusually high (200 to 400 ppm) in 0-15 cm samples taken at Site C.

Reductions in soil EC in 1993 as compared to previous years in the lower profile (60-120 cm) at Sites C and D suggests rainwater was able to move downwards through the soil profile (Figure 3). This suggests that surface sealing during rainfall events did not occur at the sites monitored.

Comparison of mean soil EC profiles between sites showed the highest levels to occur at Site C in every year (Figure 3). This corresponds well with the amount of irrigation water applied which was also the highest at Site C in 1991 and 1993 (Table 1). Soil EC levels throughout the soil profile at Site C were higher than the average EC levels in the irrigation water in 1991 and 1992 indicating salt accumulation during these years.

Soil profile EC levels were below the 2 dS m^{-1} limit at which the growth of very salt sensitive plants are reduced (McKenzie 1988) at Sites A and D. Soil EC levels in the topsoil (0-0.15 m) were slightly above the 2 dS m^{-1} limit at Site C.

Soil SAR levels in the top 15 cm were significantly lower in 1993 and 1992 as compared to 1991 and 1990 at Sites A and C (Figure 4). The reduced soil SAR levels in 1993 at Sites A and C occurred despite increases in SAR in the irrigation water. This was attributed to increased rainfall and reduced irrigation.

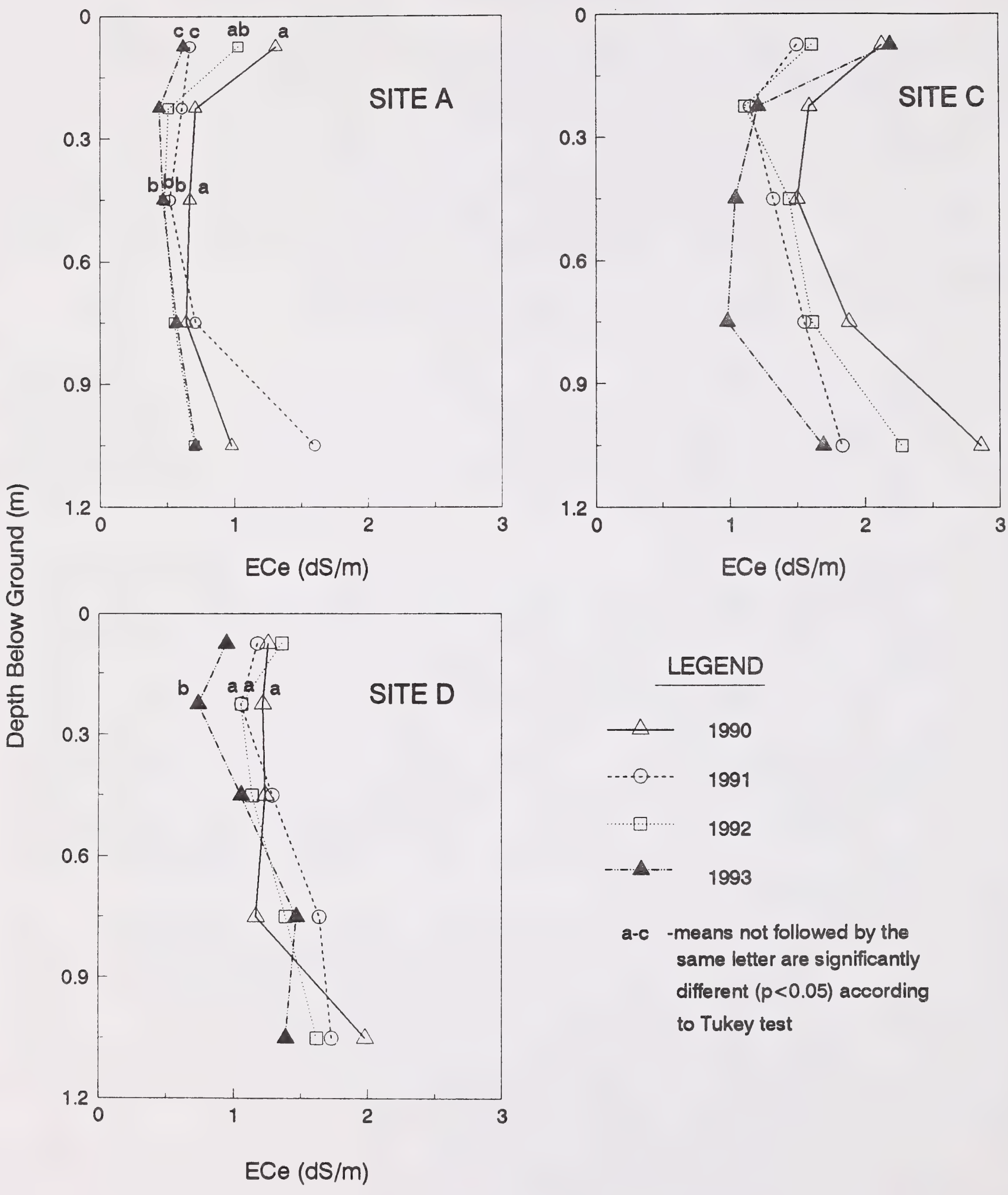

Figure 3. Average yearly EC (1990, 1991, 1992, and 1993) on irrigated land at Sites A, C and D.

Soil SAR levels in the top 15 cm were significantly lower in 1993 as compared to all other years at Site D (Figure 4). Reduced soil SAR levels in 1993 at Site D were accompanied by lower SAR levels in the irrigation water, increased rainfall and little or no irrigation.

Soil SAR levels in the 60-90 cm depth were significantly lower in 1993 as compared to 1992 at Site D (Figure 4). This reverses a trend which showed significant annual increases in soil SAR at this depth between 1990 and 1992 and showed that increases in soil SAR caused by irrigation were reversible.

Comparison of mean soil SAR profiles between sites showed the highest levels to occur at Site D and the lowest levels to occur at Site A (Figure 4). Soil SAR levels in the top 60 cm correspond very well with irrigation water SAR levels at each site in 1991 and 1992. Soil SAR levels in the top 30 cm were lower than irrigation water SAR levels at each site in 1993.

CONCLUSIONS

Mean soil EC and SAR levels in the upper 60 cm on irrigated land tend to reflect the EC and SAR of the irrigation water used at each site in "average" years where irrigation applications ranged from 150 to 300 mm. Mean soil EC and SAR levels in the upper 30 cm on irrigated land were lower than the EC and SAR of the irrigation water used at Sites A and D in a wet year (1993) where irrigation applications ranged from 0 to 60 mm.

Mean soil profile EC levels were below the 2 dS m^{-1} limit of which the growth of very salt sensitive plants are reduced in all years at Sites A and D. Mean soil EC levels were slightly above 2 dS m^{-1} in the topsoil (1992 and 1993) and 90 to 120 cm depth (1990 and 1992) at Site C.

Significant reductions in soil SAR levels in the 60 to 90 cm depth in 1993 as compared to 1992 at Site D showed that increases in soil SAR caused by irrigation were reversible. This suggests rainwater was able to move downwards through the soil profile.

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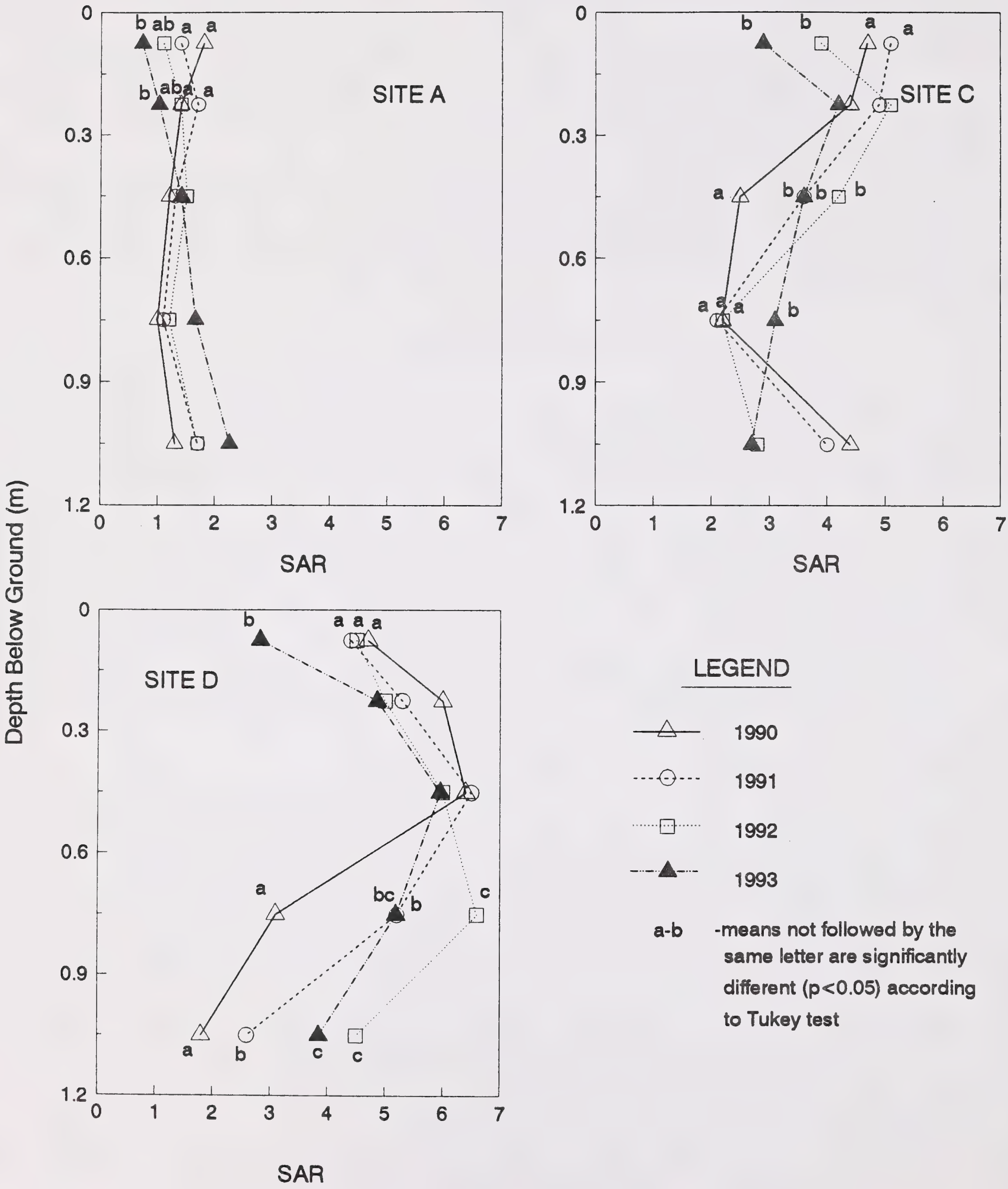

Figure 4. Average yearly SAR (1990, 1991, 1992 and 1993) on irrigated land at Sites A, C and D.

RECLAMATION EFFECTIVENESS OF POLYLINING ALONG LATERAL 17-G (SW 35-21-13 W4) IN THE EASTERN IRRIGATION DISTRICT

D. P. Graveland[3]

INTRODUCTION

The Irrigation Rehabilitation and Expansion (IREP) Reclamation Effectiveness Study was initiated in 1988 to examine the success of various canal seepage control measures on reclaiming seepage-affected land. The study responds to the lack of documentation of soil reclamation (Coopers and Lybrand 1987) following the rehabilitation of irrigation canals using various seepage-control measures.

Soil reclamation is achieved by a lowering of the water table followed by a reduction in soil salinity to levels which will not affect crop growth. Previous research found the elimination of seepage does not guarantee soil reclamation will occur (Bennett 1990). Water table and salinity levels next to canals are also influenced by surface drainage, local and regional groundwater flow, and internal drainage of the soil and geologic materials (Bennett 1990; Millette et al. 1992). Installation of subsurface drainage, changes in irrigation practices and/or control of groundwater recharge may be needed, in addition to canal rehabilitation, to achieve reclamation.

This study reports on changes in water-table levels adjacent to a canal in the Eastern Irrigation District which was rehabilitated in 1993 by relocation and membrane lining.

METHODS

Six water-table wells (WTW's) were installed adjacent to Lateral 17-G in the spring of 1992 (MPE Engineering 1992) (Figure 1). These WTW's were used to document seepage prior to canal rehabilitation. Water-table wells were installed to a depth of six m and were monitored once prior to, and twice after, canal turn on.

Five WTW's were installed adjacent to the relocated lateral in the spring of 1993 (Figure 1). Water-table wells, installed to depths between 3.0 and 4.5 m, were constructed of 37 mm (ID) PVC pipe. Water-table wells were slotted to within 0.15 m of ground surface and were backfilled with sand to the top of the slots. A bentonite plug was installed from a depth of 0.15 m to ground surface. The WTW's installed in the spring of 1993 were located outside the area covered by a centre pivot, which was also installed in the spring of 1993. There was no irrigation on the land before this time. Post canal rehabilitation water-table levels were monitored between May of 1993 and February of 1994. Precipitation data was compiled from Environment Canada station at Brooks (Alberta Agriculture Weather Summary).

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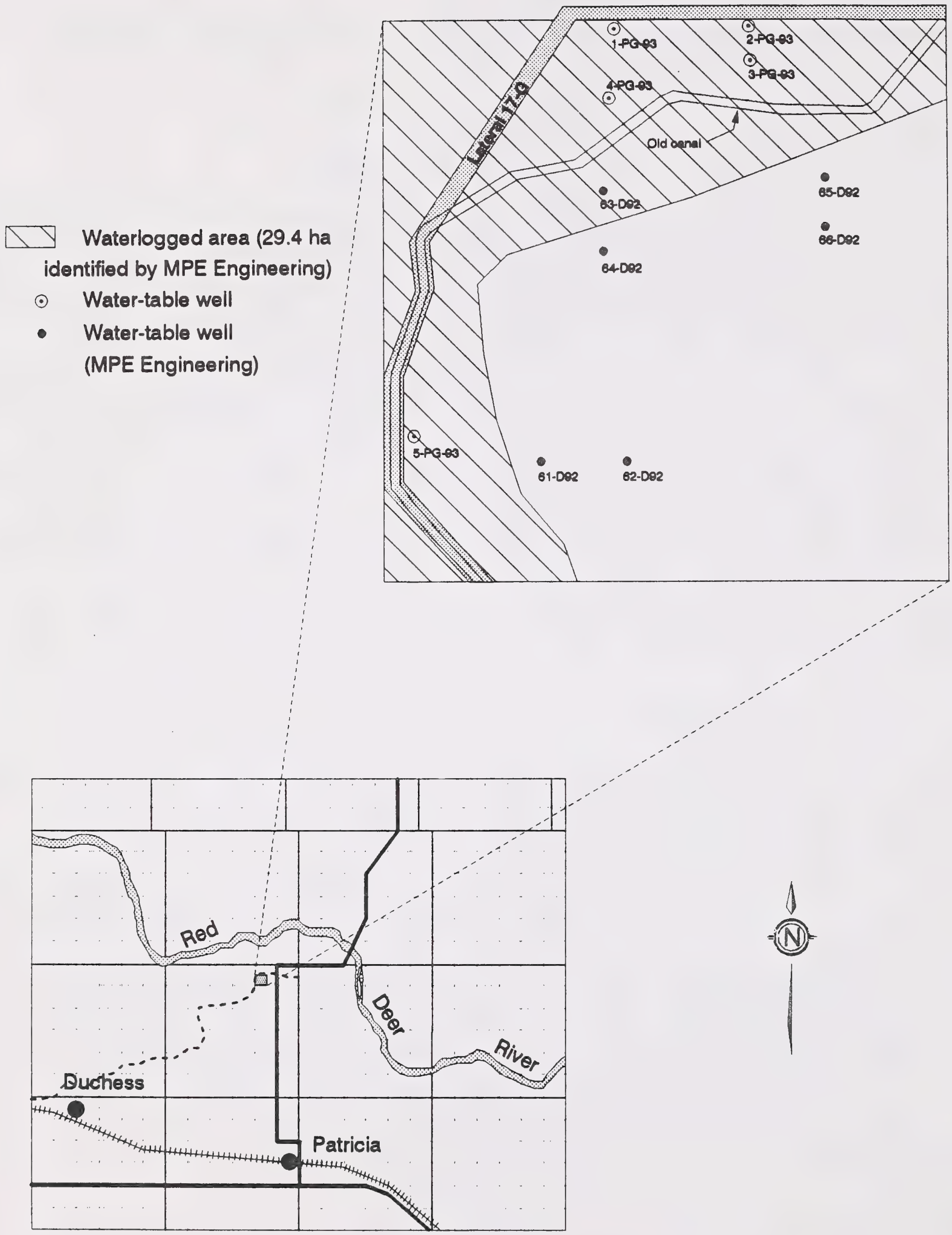

Figure 1. Map showing water-table well locations adjacent to Lateral 17-G in the SW 35-21-13 W4.

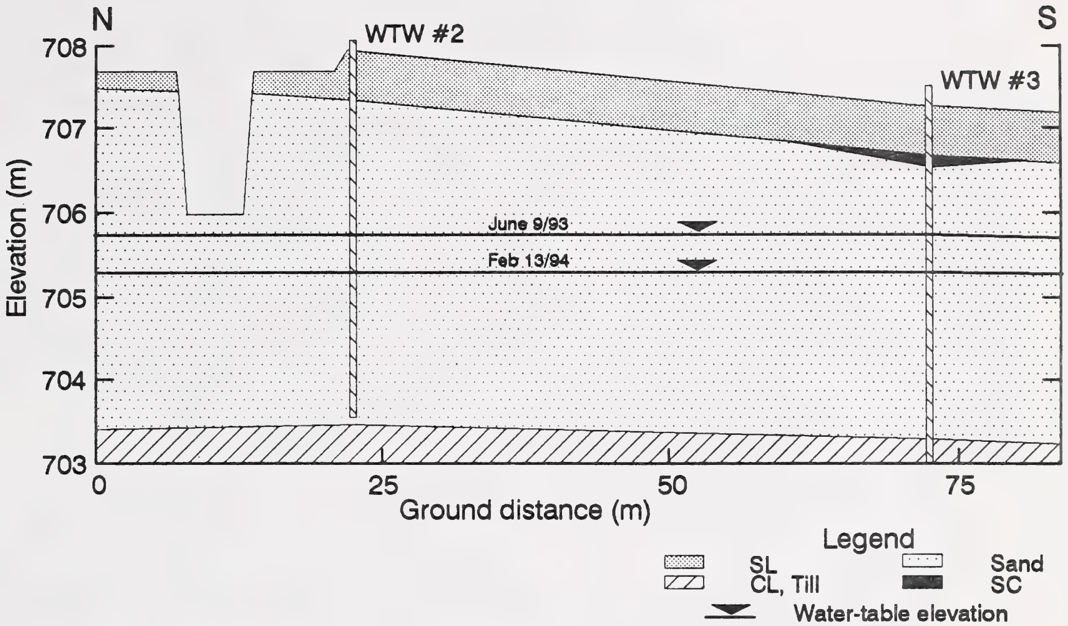

Figure 2. Cross section at WTW's #2 & #3 showing water-table elevations.

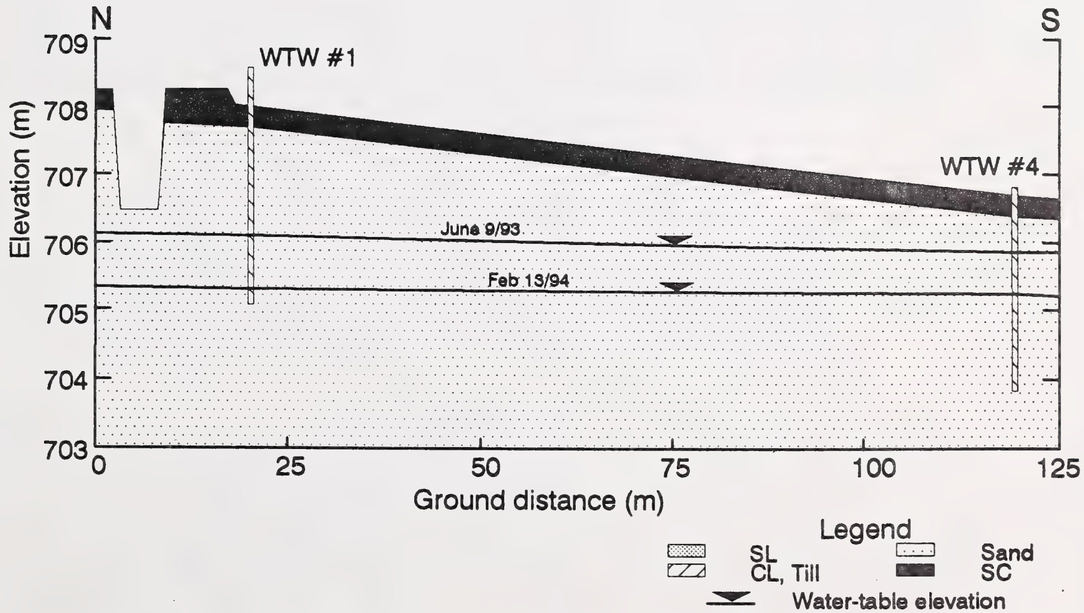

Figure 3. Cross section at WTW's #1 & #4 showing water-table elevations.

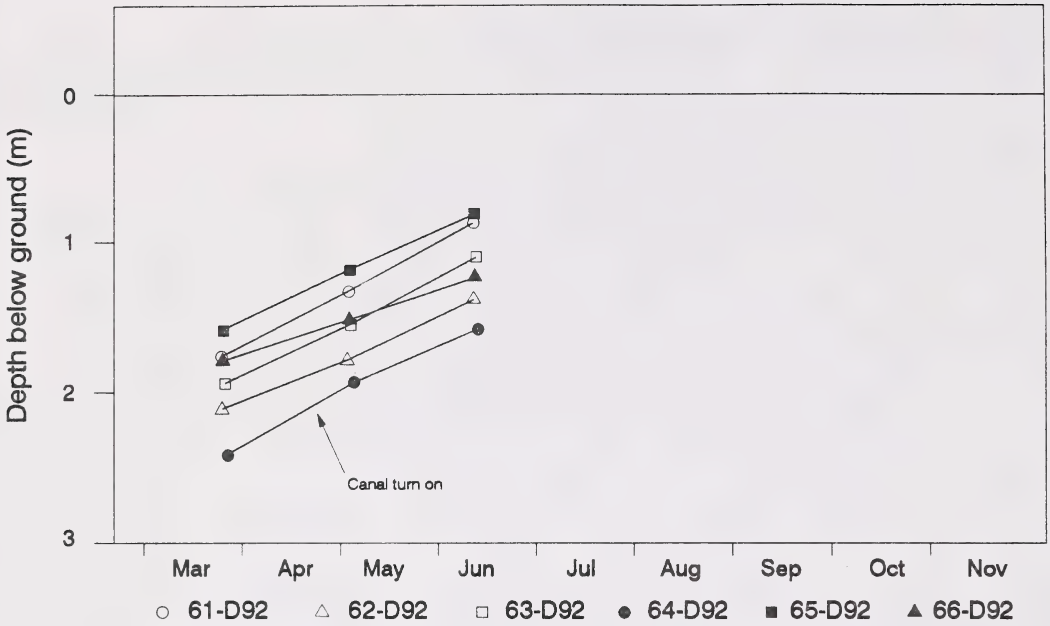

Figure 4. Water-table hydrographs at EID IREP reclamation site in 1992 before rehabilitation (SW 35-21-13 W4).

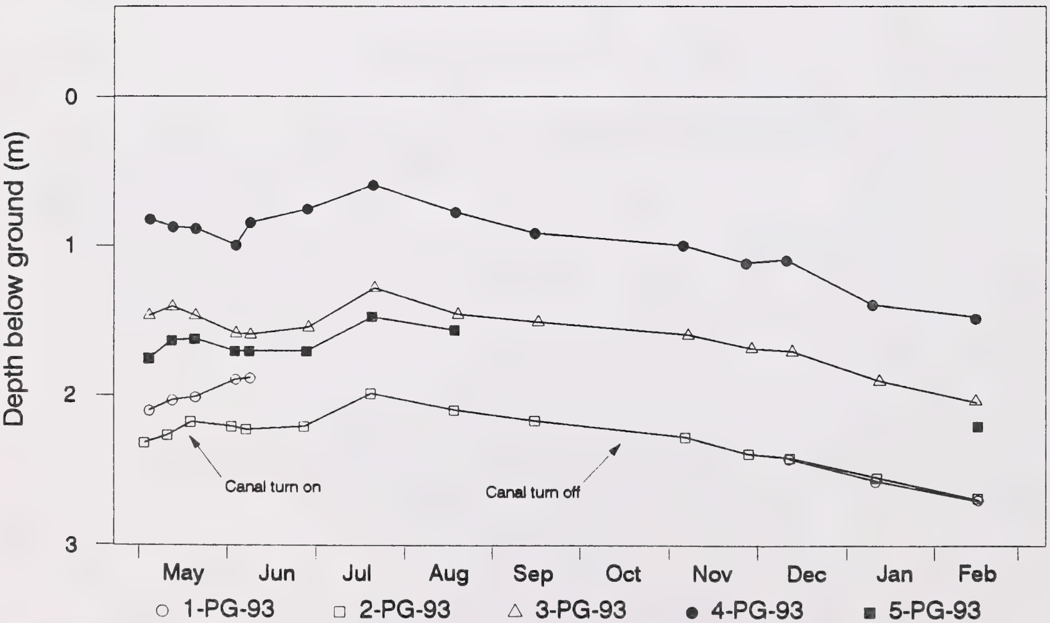

Figure 5. Water-table hydrographs at EID IREP reclamation site in 1993 after rehabilitation (SW 35-21-13 W4).

RESULTS AND DISCUSSION

The site was level to undulating with slopes ranging from 2 to 5%. Soil parent material was mainly sandy-loam textured fluvial deposits overlying till at a depth of 4.0 m or more (Figures 2 and 3). Soil profiles were described as Orthic Brown Chernozemic (Kjearsgaard et al. 1983). Plant growth in the seepage area was willows and grass both before and after rehabilitation.

Pre-canal rehabilitation hydrographs show a steady increase in water levels following canal turn on in 1992 (Figure 4) which shows evidence for canal seepage. Post-canal rehabilitation hydrographs show little or no response in water levels to canal turn on and shut off (Figure 5). In addition, the flat water-table gradient on June 9, 1993 shows no evidence of canal seepage (Figures 2 and 3). Seepage from irrigation canals usually causes a strong water-table gradient away from the canal.

There was not a substantial drop in the water table, despite the apparent effectiveness of the canal lining in controlling seepage. The water table was only slightly lower in 1993 after canal rehabilitation than the peak level observed in 1992. The differences between the two years were not related to rainfall because rain during the period March 15 to June 15 was similar between the two years (102 mm in 1992 and 110 mm in 1993, Table 1). Some of the apparent differences between years might be due to different locations of WTW's, or the very limited monitoring of WTW's during 1992.

Table 1. Monthly precipitation amounts (mm) for March to October in 1992 and 1993 (SW 35-21-13 W4)

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1992	0.4	13.8	42.0	71.4	58.4	34.4	19.6	19.7
1993	16.2	36.8	26.2	80.6	42.2	67.0	33.8	14.1

CONCLUSION

Lining and relocating Lateral 17-G appears to have eliminated canal seepage. This was evidenced by a lack of rise in the water-table adjacent to the canal following canal turn on in 1993. This rise was apparent in 1992 prior to rehabilitation. There was only a slight drop in water-table levels since canal rehabilitation. More time is required to study the effects of eliminating canal seepage.

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IRRIGATION - WATER APPLICATION

A COMPARISON OF SURGE FLOOD IRRIGATION TO CONVENTIONAL FLOOD IRRIGATION ON BORDER DIKED FIELDS

G.A. Snaith and J.M. Bakker [4]

INTRODUCTION

This study applies surge flood irrigation methods to Southern Alberta field conditions. During this introductory year, a manual surge irrigation scheme was set up to evaluate the potential of surge flood methods in this area. The sites are border diked flood fields located at Tilley, Alberta. Two field sites are being studied, one with a 354 meter field length and one with a 777 meter field length. These fields approximate typical 1/4 mile and 1/2 mile irrigation schemes. In each case surge flood irrigation is compared to conventional flood techniques.

METHODS AND PROCEDURE

The two project sites were chosen to emulate typical flood fields in the Brooks area. Field A is a 1/4 mile long alfalfa hay field and Field B is a 1/2 mile long soft wheat field. Each field uses a different water delivery system. Field A uses flexible gated pipe connected to a centrally located turnout from the district canal. Field B uses a permanent grassed head ditch with three PVC pipe turnouts in each border.

Both Field A and Field B were set up with the same testing objectives, to compare surge flood and conventional flood irrigation. Field monitoring included soil moisture, water table fluctuations, and volumetric flow onto the field. To accomplish this the following equipment was installed: two metre long neutron probe access tubes at the top, centre and bottom of each border to monitor soil moisture; water table wells at the top and bottom of each border to monitor ground water fluctuations; a Collins flow meter was installed in the delivery of Field A and a propeller meter was installed in the supply culvert of Field B to monitor the flow of water onto the field. Monitoring the soil moisture and ground water levels began in May, continuing biweekly. Monitoring during the irrigations consisted of recording the volumetric flow rates onto the field and recording the advance times of each irrigation.

Borders under conventional flood irrigation were irrigated until the wetting front reached the bottom of the field. At that time, the water was turned off. The procedure for irrigating the surge flood borders was set up based on the distance the wetting front reached down the field. Four surge cycles were initiated with water being changed when the advance reached the quarter, half, three quarter, and full length of the field.

<u>Field A</u>

Field A is a seventeen hectare border diked field of alfalfa hay with clay loam soil. The field set up is shown in Figure 1. The surge study area consists of the central eight

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borders, using four on each side of the delivery point. The borders are 19 metres wide, average 354 metres in length, and have a downfield slope of 0.3%.

Flexible gated pipe runs east and west from the delivery point along the south edge of the field. The Collins flow meter is installed in the main supply conduit located at the turnout.

Irrigations took place on June 5 and August 16. Borders were irrigated two at a time, splitting the flow between east and west. Four borders were irrigated using surge flood techniques. Four borders were used as controls and were irrigated using conventional flood techniques.

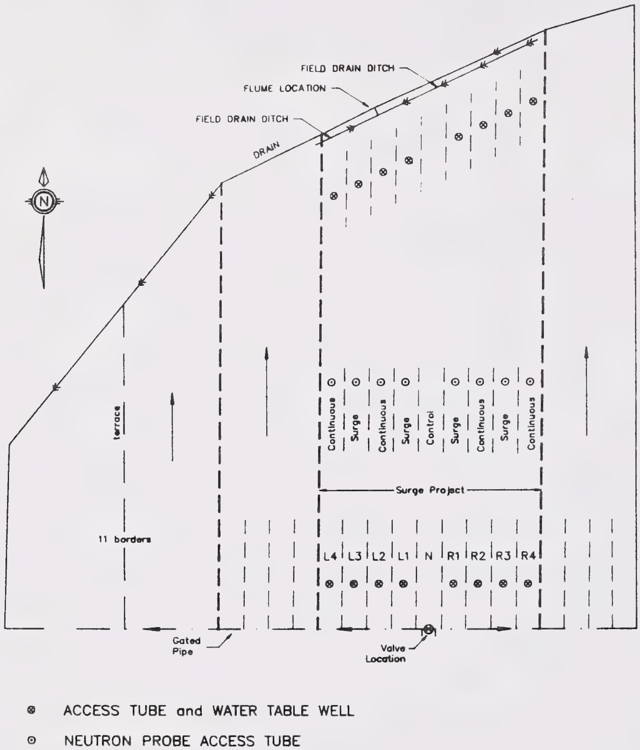

Figure 1. - Field A

<u>Field B</u>

Field B is a 7.7 hectare soft wheat field with 4 borders as seen in Figure 2. The soil in this field is clay loam to sandy clay loam. Water delivery is via the permanent grassed head ditch at the east end of the field. The borders have a 0.45% downfield slope, are 19 m wide, and average 777 m in length.

Irrigations took place on June 7 and August 5. The procedure for irrigating both the conventional flood and the surge flood borders was identical to the procedure used for Field A for the irrigation on June 7. The second irrigation, on August 5, was determined by replicating the output of a program from a surge valve controller currently on the market. The program uses the conventional flood treatment advance time as an input. It then

determines the number and duration of surge cycles required for the field. In this case it provided a program of five cycles, each increasing slightly in duration. During the replication of this program water did not reach the end of the borders during the fifth cycle and a sixth cycle had to be initiated.

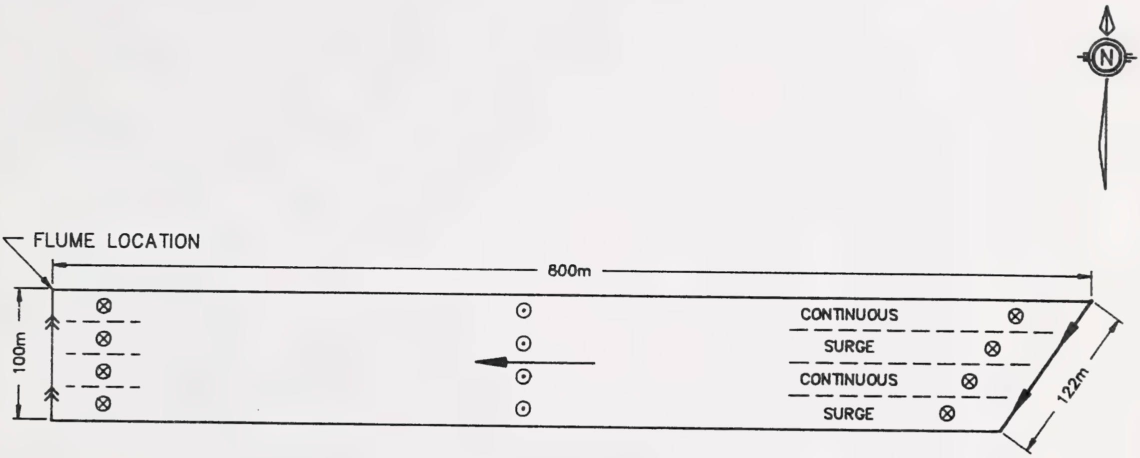

Figure 2. - Field B

RESULTS AND DISCUSSION

Results from this year's data collection are preliminary. Some time savings , no reduction in yield and improved application uniformity were achieved under surge flood conditions.

Field A

Monitoring of soil moisture on this field indicated a general pattern of excess soil moisture at the top of the field and insufficient moisture at the bottom prior to each irrigation. Each irrigation achieved field capacity at the top and centre sampling points in the field. Soil moisture increased but did not achieve field capacity at the bottom sampling sites. Measurements from the water table wells indicate a rise in the water table after each irrigation.

Flow rates measured through the main supply conduit averaged 99 litres per second (3.5 cfs). The west leg of the gated pipe carried approximately fifty five percent of the flow while the east leg carried forty five percent of the flow. Wetting front advance times are indicated in Figure 3. This figure depicts the advance times for the conventional (cts) flood treatments, the advance times of each surge, and the total surge flood advance times. A comparison of the conventional flood treatments to the surge flood treatments shows that there was a sixteen percent time savings during the first irrigation but virtually no time savings during the second irrigation. Further examination of Figure 3 indicates that some

sealing of the soil surface was taking place during each surge cycle. The fine soil texture, soil compaction, some fluctuations in the flow rates and rainfall during the second irrigation may all have contributed to the minimal time savings during the second irrigation.

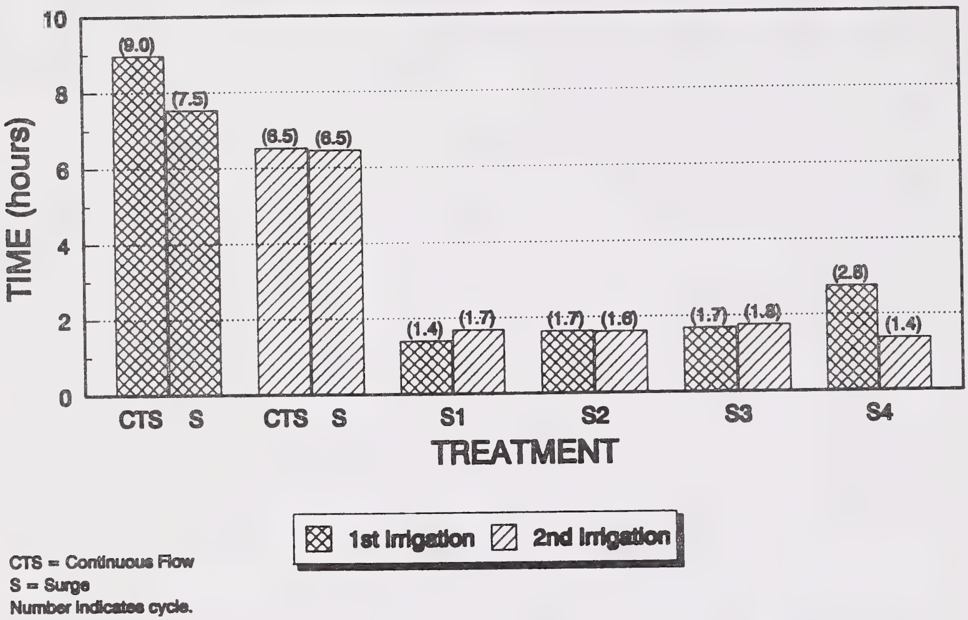

Figure 3. Surge Advance Times - Field A

Yield on Field A is consistent between the two treatments. The surge flood treatments yielded slightly higher with an overall average of 9.6 tonnes per hectare, dry matter. Conventional flood treatments yielded 9.0 tonnes per hectare. The surge flood treatment yielded slightly higher than the conventional treatment for both cuts.

Field B

The results from Field B are more comparable to results from other surge irrigation studies. Soils on this field vary between a clay loam and a sandy clay loam. As in Field A, soil moisture varied considerably across the field with a pattern of excess moisture at the top of the field and inadequate moisture at the bottom. Again, as with Field A, the top and centre sampling sites on the field achieved field capacity after each irrigation. At the bottom sampling sites there was some improvement in application uniformity under the surge flood treatment. The conventional flood borders had only 6 mm of additional moisture compared to the surge flood borders despite a much longer opportunity time.

Water table wells at the top of this field indicated a substantial increase in the height of the water table after each irrigation. At the bottom of the field, the water table wells

registered a water table below 1.5 metres on the conventional flood irrigation treatments after each irrigation, but otherwise remained dry.

The flow of water onto this field was stable and consistent for both irrigations. Flow was maintained at 85 litres per second (3.0 cfs). Wetting front advance times can be seen in Figure 4. There was a seventeen percent time savings during the first irrigation and a thirteen percent time savings during the second irrigation.

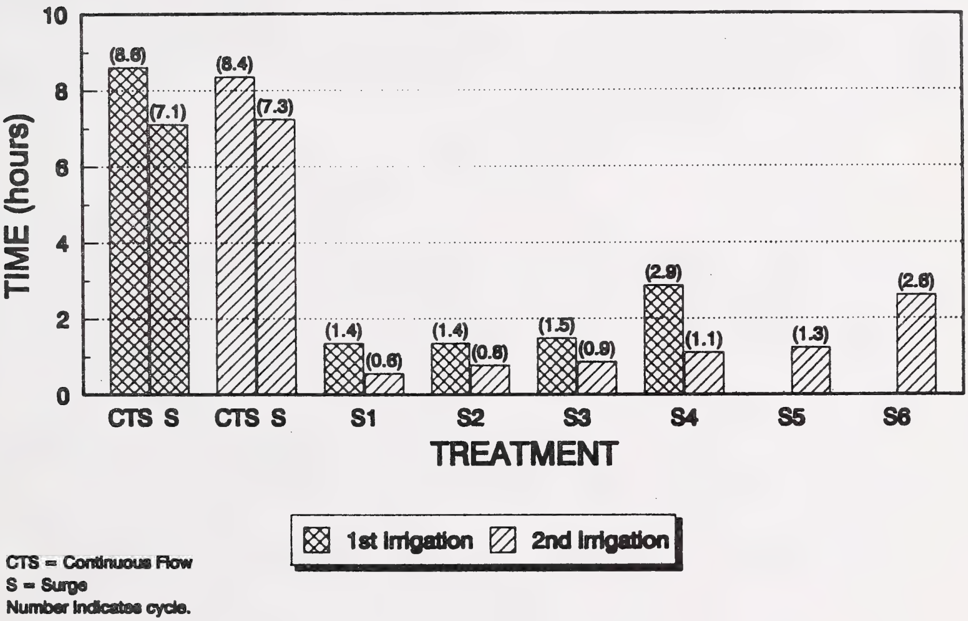

Figure 4. Surge Advance Times - Field B

Yield and protein levels of the soft wheat from this field do not reflect a difference between the treatments. The yields were consistent between the treatments and along the length of the border. The average yield was 5385 kg/ha. The average protein value for this field was 12.4%, increasing from the top of the field to the bottom of the border where the soil was much drier.

CONCLUSIONS

As the majority of surface irrigation in the Brooks area takes place on fine textured soils, field sites with that particular soil characteristic were chosen. Research indicates that fine textured soils do not respond as well as medium textured soils to surge flood irrigation. The results from the 1993 irrigation season show some improvement in advance time resulting in time and water savings, and some improved application uniformity on this clay

loam soil. Yield results from both fields indicate no difference between the surge flood and conventional flood treatments.

Modifications to the current project plan include altering the number and duration of surge cycles to obtain the best combination of on and off times for this soil type; expansion of the project to fields with medium textured soils and more sensitive crops; and further instrumentation to obtain a complete water balance and more detailed application uniformity.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of the cooperating producers, Edwin and Josephine Bronsch, Farming for the Future, Alberta Soft Wheat Producers Commission, Irrigated Alfalfa Seed Producers Association of Alberta, and members of the project's technical advisory committee.

CHEMIGATION TRIALS USING A LOW PRESSURE CENTRE PIVOT

G. Cook, P.Eng.[5], R. Esau, P.Ag.[6], Dr. D.S. Yu[7], Bryan Farries[8]

INTRODUCTION

A chemigation trial was conducted using a three tower pivot located at the Ag Canada Research Substation in Vauxhall, Alberta. The pivot had previously been converted to a low pressure system operating at 105 kpa, with drops extending to within 0.25 m of the ground. An Agri-Inject® chemical injection system with appropriate backflow and safety equipment was used to inject pesticides into the irrigation stream. Crops were seeded in concentric rows. Trials using Metribuzin (Sencor®) and EPTC (Eptam®) for weed control in potatoes and Cypermethrin (Cymbush®) for control of European corn borer (ECB) in sweet corn were carried out.

METHODS

<u>Herbicide Trial:</u>

Eighteen 5 m by 10 m plots in a randomized complete block design were planted under the second span of the low pressure pivot. (Figure 1.) These plots were part of a trial to determine the efficacy of Metribuzin and EPTC as a tank mix applied through an irrigation system. Treatments included:

1. Control
2. Preplant ground applied and incorporated tank mix of Metribuzin at 0.28 kg active ingredient/hectare (ai/ha) and EPTC at 3.4 kg ai/ha.
3. Pre-emergent chemigated tank mix of Metribuzin at 0.28 kg ai/ha and EPTC at 3.4 kg ai/ha.
4. Pre-emergent chemigated tank mix of Metribuzin at 0.55 kg ai/ha and EPTC at 3.4 kg ai/ha.
5. Post hilling chemigated tank mix of Metribuzin at 0.28 kg ai/ha and EPTC at 3.4 kg ai/ha.
6. Post hilling chemigated application of Metribuzin at 0.28 kg ai/ha.

Weed populations were determined by a count and by a visual evaluation. Crop injury was determined after all applications had been completed. Yield was determined by harvesting 10 m^2 from each plot. Total yield, total marketable yield and specific gravity were determined for each treatment.

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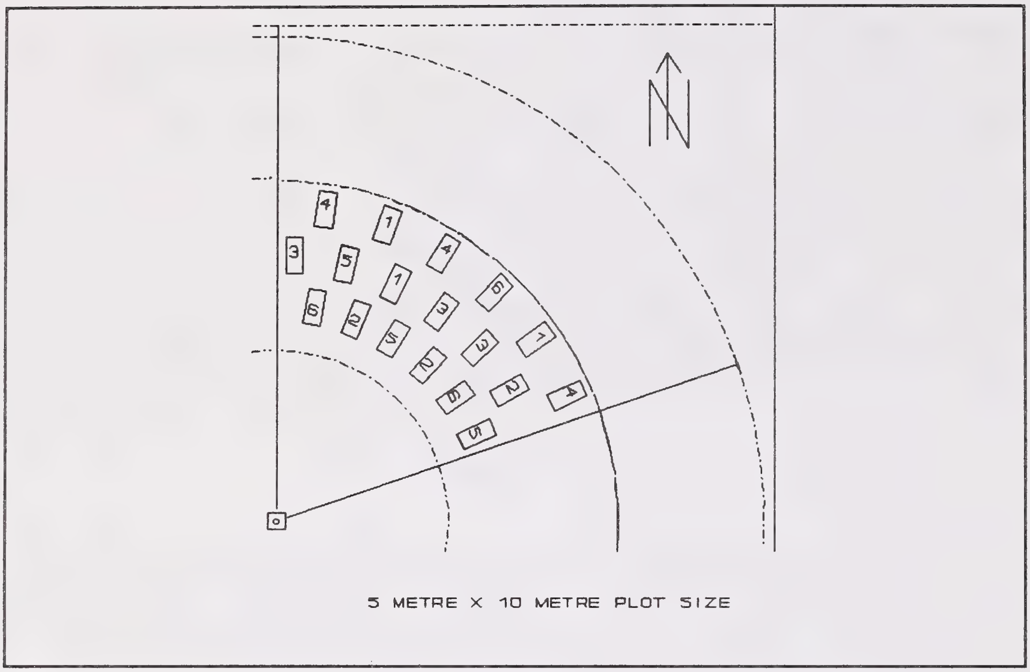

Figure 1 Herbicide Plot Layout

Nelson Spinner® sprinklers were used for chemical applications on the potato plots. The ground applied check (Treatment #2) was done on May 13, prior to seeding. Treatments #3 and #4 were applied on May 25, prior to potato emergence. These treatments were applied with 18 mm of irrigation water to incorporate the chemicals. Treatments #5 and #6 were applied on June 30 following the final hilling operation. These treatments were applied with 12 mm of irrigation water to incorporate the chemicals. After every chemigation treatment, all remaining plots were irrigated with the same amount of water. Treatments #5 and #6 were delayed approximately 2 weeks due to wet weather. Weed counts were conducted on all plots, including the control (Treatment #1), on July 24.

<u>Insecticide Trial:</u>

Approximately 3 ha of sweet corn were planted in the three remaining quadrants of the centre pivot. Corn was planted in concentric rows at 1 metre spacing with a plant population of 62,000/ha. The south west quadrant had Cypermethrin applied to control ECB through the irrigation system. This was done by placing Nelson Spinner® sprinklers at tassel height as well as by placing Senninger Qaud Spray® sprinklers in chemigation mode in the crop canopy. The north west quadrant was used as a control. The south east quadrant was a release site for a parasitic wasp, <u>Trichogramma evanescens</u>, to control ECB. 480 plants were taken from each treatment and evaluated for ECB damage.

The sweet corn in the south west quadrant was chemigated with Cypermethrin on August 4. Timing of chemigation was based on moth catch in the field and degree days accumulated. Chemigation treatments were applied with 3 mm of irrigation water.

RESULTS

This is the first year of a two year project. Data collected is in support of minor use registrations for chemigation of the Metribuzin - EPTC tank mix and chemigation of Cypermethrin. Detailed analysis of field data will follow the second year of trials.

In the potato trial, there were insufficient weeds to perform a statistical analysis. A visual rating of weed control showed more weed escapes in the post hilling treatments. These weeds were typically in the potato row, not in the furrows. This may have been due in part to the extremely late application of the post hilling treatments caused by the wet weather. Potato yields were not significantly reduced by the herbicide treatments and specific gravity was unaffected.

In the corn trial, a corn borer damage assessment was carried out by examining 480 plants in each of the three quadrants. These plants were examined in situ at regular intervals over the entire quadrant. Results are shown in Table 1. These results show that the chemigation application of Cypermethrin was effective in controlling ECB.

Table 1 European Corn Borer Control

	Plants w/ ECB	Cobs w/ ECB	Larvae	Reduction %
Control	44	15	98	
Chemigation	7	0	15	84
Wasp Release	5	0	8	89

The chemigation equipment proved easy to calibrate and operated very well. Some difficulties arose in maintaining proper pressure regulation of the centre pivot. There was no noticeable crop injury from the chemical applications. Wet weather delayed the final hilling of the potatoes and therefore delayed the final application of herbicide. Wind drift was very slight with the low pressure sprinkler package. Chemigation appears to show promise for applications in southern Alberta. Following year two of the study, applications for minor use registrations may make these treatments available to producers.

CONCLUSIONS

Chemigation equipment is reliable and easy to use. It shows potential for application in commercial operations in southern Alberta. The first applications will probably be in the special crops area due to the high use of pesticides, the high value of the crop, and the high numbers of centre pivot irrigation systems in use.

Chemigation control of weeds in potatoes has potential. Post hilling treatments may be less effective for total weed control but may offer an option for late control of problem weed outbreaks. Incorporating herbicides with irrigation water offers time and dollar savings through reduced labour and field equipment requirements.

Chemigation of insecticides shows promise. Advantages of chemigation are reduced labour and field machinery costs. Additional benefits are derived from less crop damage for

insecticide applications late in the season. Increased flexibility offered by the use of existing equipment as opposed to using specialized spraying equipment or custom operators is also a benefit.

Chemigation can be performed safely. Operator exposure to pesticides can be minimized due to the hands off nature of the operation. Application windows can be widened due to the ability to apply pesticides at night and in wet field conditions.

Chemigation can save substantial equipment costs. Chemigation equipment can be shared between several irrigation systems.

ACKNOWLEDGEMENTS

The author would like to thank field staff at the Vauxhall substation and staff of Alberta Agriculture in Vauxhall for their assistance in this project. Thanks also to Agriculture Canada for permitting the use of the Vauxhall facility for these trials.

The equipment used in these trials was put in place through generous donations from Senninger Irrigation, Nelson Sprinkler Corporation, and Agri- Inject. Support from their local dealers is also greatly appreciated.

This project was initiated as an extension of the Farming For The Future Demonstration Project, #92-F006-1, Demonstration of Low Energy Precision Application Equipment for Irrigation and Chemigation of Potatoes.

TRICKLE IRRIGATION PRACTICES IN SELECTED SASKATOON ORCHARDS, GRANDE PRAIRIE AREA

D. Roll[9]

INTRODUCTION

Saskatoons are produced commercially on nearly half of the 400 hectares of planted orchard in Alberta. Nearly two-thirds of present berry production is from orchards in the Grande Prairie area using trickle irrigation. Water is delivered to each tree with a single 2, 4, or 8 litre per hour (L/h) point source emitter. There is very little published information on irrigation water and equipment requirements for this crop.

It is common practice among growers to establish creeping red fescue (*Festuca rubra* L.) and other grasses between the saskatoon rows to facilitate machine harvesting, especially under wet soil conditions. It is not known if the presence of grass affects the total irrigation water requirement, or if present systems are capable of applying sufficient water to maintain adequate soil moisture for both saskatoons and grass.

The objective of this investigation was to determine if 2 L/h emitters and farm water application practices among growers were sufficient to maintain soil moisture above 50% management allowed depletion, an optimum level for tree growth (Eakes, et.al. 1985).

METHODS

Several saskatoon growers with producing orchards in the Grande Prairie area were contacted in June 1993 to review their irrigation practices for the preceding month. May was exceptionally dry at Grande Prairie (Figure 1), so orchard soil moisture levels were affected more by irrigation water application than by natural precipitation.

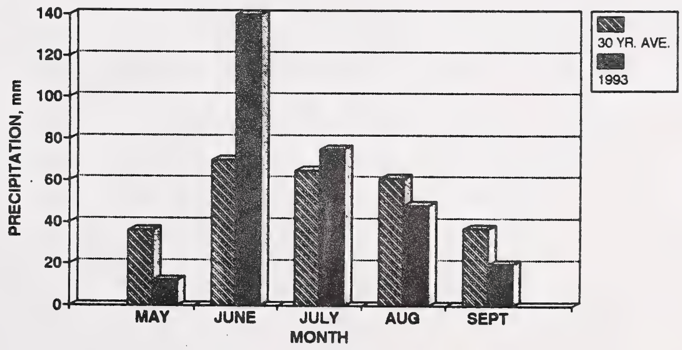

Figure 1. Growing season precipitation for Grande Prairie, 1993 and 30 year average.

[9]Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Airdrie, Alberta T4B 2C1

Seven growers provided data for their orchards to indicate the total amount of water applied during the month of May. For each orchard, water applied by irrigation plus precipitation for the month was plotted against calculated values for 50% management allowed depletion of soil moisture, moisture use by grass for the period, and soil moisture levels that could be maintained with 2 L/h emitters operated five hours per day. Soil moisture calculations were made assuming a clay loam soil. Root zone soil volumes were based on a 1.8 m wide by 0.75 m deep root zone, with a 0.9 m emitter and tree spacing.

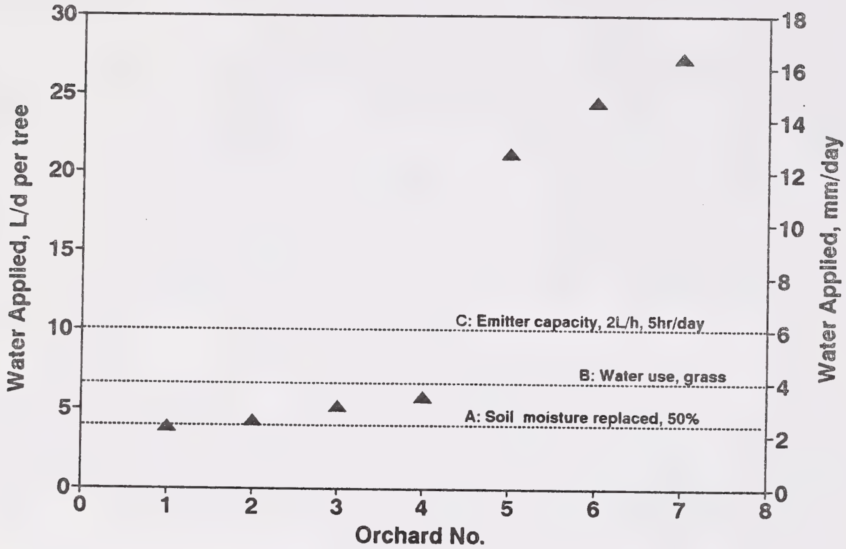

Figure 2. Mean daily water applied per tree for seven orchards, May 1993.

RESULTS AND DISCUSSION

Mean daily water applied per tree for each orchard during May is shown in Figure 2. Soil moisture was maintained above 50% of management allowed depletion (line A) in six of seven orchards for the period, assuming soil moisture was near field capacity at the beginning of the growing season. In four orchards, soil moisture was replenished one to one and a half times, while three had sufficient water applied to replenish moisture up to seven times. Water application varied from 2 - 16 mm/day (mm/d) with a mean value of 7 mm/d. Irrigated alfalfa is considered to have a peak use rate of 8 mm/d, so applications of 16 mm/d for saskatoons seem excessive. This was possibly due to excessive irrigation, unaccounted irrigation system or storage losses, inaccurate reporting of actual amounts applied, or extra moisture withdrawals by grass from the tree root zone, for which additional irrigation water was required.

Total water applied in four orchards (orchards one to four) was less than the calculated use by grass for the period. This suggests that saskatoons required less water than grass.

Since herbicides were used to eliminate grass (thus competition for soil moisture) at the immediate base of the tree, it is expected that the major water uptake was by saskatoons alone. Soil moisture depletion for the given root zone volume was calculated to be less than 50% for the period, indicating that the water applied was sufficient for saskatoons. It is possible that soil moisture was withdrawn from the tree root zone by grass growing between the tree rows, which would result in a water requirement higher than for saskatoons exclusively. More than 6 litres per day (L/d) per tree were required to keep up to the 4 mm/d expected use by grass alone. Figure 2 shows that any soil moisture depletion by grass near the tree rows (line B) would have required higher actual water applications to maintain enough soil moisture for both saskatoons and grass.

In the same four orchards, actual daily water applications were considerably less than the 10 L/d (line C) that the systems were designed for using 2 L/h emitters. If operated as designed, more than twice the actual amounts could have been applied. However, to apply the reported high of 27.3 L/d (orchard seven), 14 hours of system operation were required. Two L/h emitters were still adequate if pipe and pump components could supply the entire orchard at one time. Operating time would be less using 4 L/h emitters with compatible soil infiltration rates.

CONCLUSIONS

Trickle irrigation systems with 2 L/h emitters were adequate to keep up to saskatoon water needs and maintain adequate soil moisture.

Existing irrigation practice suggests that many orchards did not receive enough water in May 1993 to adequately meet the demands of both saskatoon trees and grass in the orchards. Enough water could be applied by operating the systems longer. It is also possible that some orchards were irrigated to excess. Irrigating to field capacity in late fall would reduce demands on the irrigation system the following year. Growers could manage their irrigation more effectively by monitoring soil moisture and emitter discharge, and by using flow meters on their irrigation systems.

Research is needed to determine actual water needs and root distribution for saskatoons, water infiltration in gray luvisols, and the effects of grass on orchard irrigation water requirements. The application of new technology such as heat conductance stem flow gauges to monitor transpiration may give useful data on actual water use by saskatoons.

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FALL IRRIGATION STUDY - 1993

R. Riewe, P.Ag., B. Handerek[10]

INTRODUCTION

The purpose of this report is to examine the effects of varied fall irrigation applications and cultivation practices on spring soil moisture conditions within a one metre root zone.

Increased fall irrigation application amounts showed higher spring soil moisture levels but corresponding increases in irrigation water lost to evaporation and/or deep percolation for all plots located in the cultivated test section. An application of 50 mm of water raised spring soil moisture conditions within a 0-75 cm soil depth while both 100 mm and 150 mm of fall irrigation increased spring soil moisture within the entire one metre zone.

Within the stubble covered section of the site increased fall application amounts resulted in elevated spring soil moisture levels but evaporative and/or deep percolation losses were varied. Fall irrigation applications of 50 mm, 100 mm and 150 mm produced elevated spring soil moisture within a 0-100 cm soil depth. The 150 mm fall irrigation application was the only treatment to perform significantly better than stubble covered dryland.

METHOD

The time frame for the study is the overwinter period from final fall irrigation (October 5, 1992) to spring seeding (April 1, 1993).

The project is located in the SE ¼ of 2-10-21-W4, approximately 10 km north of Lethbridge. The plot area for the project was split into two parts: half of the area was in wheat stubble and the other half was cultivated. A randomized plot design was used in each of the areas. Three different irrigation treatments and a dryland plot were replicated three times in each area. The size of each plot was 6.1 m x 6.1 m (20' x 20') with a 9.15 m (30') buffer zone around each plot.

The irrigated treatments consisted of 50 mm, 100 mm, and 150 mm of water applied. A non-irrigated treatment was included as a check. Irrigation water application was measured by means of a Tru-chek rain gauge located at ground level in the centre of each plot. Temperature, precipitation and sunshine hours information was obtained from Agriculture Canada at Lethbridge.

Prior to fall irrigating, a 1.5 m long aluminum access tube was installed centrally in each plot. Using a Campbell Pacific neutron probe, soil moisture readings were taken at 25 cm intervals to a depth of 1.5 m. The 100-150 cm depth was monitored for possible deep percolation of soil moisture beyond the 0-100 cm zone. Soil moisture monitoring was performed on a weekly basis during late fall and early spring and as weather or field conditions permitted during winter.

RESULTS

The winter of 1992-93 was considerably cooler with more precipitation than this same

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time period one year ago. During the 1992/93 over winter period, there were 114 days (63.7%) that had maximum day time temperatures greater than 0°C and 37 days (20.7%) with minimum day time temperatures greater than 0°C. There were 13 days (7.3%) that had day time temperatures greater than 15°C. During the 1991/92 over winter period, there were 146 days (82%) that had maximum day time temperatures greater than 0°C and 57 days (32%) with minimum day time temperatures greater than 0°C. There were 28 days (16%) that had day time temperatures greater than 15°C.

Over winter precipitation for this time period is on average 116.6 mm. In 1992-93, the plot area received only 100.7 mm of the precipitation. Climate data given in Table #1 was recorded by the Agriculture Research Centre in Lethbridge.

TABLE #1. SEASONAL CLIMATIC DATA

	MEAN TEMP (°C)		TOTAL PRECIP. (mm)		TOTAL SUNSHINE (HOURS)	
MONTH	1992/93	LONG TERM	1992/93	LONG TERM	1992/93	LONG TERM
Oct/92	7.2	7.0	13.7	19.2	133.2	172.0
Nov/92	0.8	-0.7	29.4	18.6	98.4	113.2
Dec/92	-10.8	-5.8	18.0	18.6	88.1	94.0
Jan/93	-10.5	-8.6	6.4	18.7	144.5	98.7
Feb/93	-6.7	-6.4	18.0	17.5	182.2	123.9
Mar/93	2.1	-1.7	15.2	24.0	162.2	163.2

Table #2 describes the soil characteristics of the project area.

TABLE #2. SOIL PHYSICAL PROPERTIES

DEPTH (cm.)	BULK DENSIT Y (g/cm³)	FIELD CAPACITY (mm)	PERMANENT WILTING POINT (mm)	AVAILABLE WATER (mm)
0-25	1.4	106	49	57
25-50	1.4	112	48	64
50-75	1.4	107	49	58
75-100	1.35	107	47	60
100-125	1.35	103	49	54

Treatment A represents 50mm of irrigation water applied; Treatment B - 100mm of water applied; Treatment C - 150mm of water applied; and Treatment D - non irrigated. The letters "S" and "C" after each treatment refer to Stubble or Cultivated.

Due to the large amount of precipitation received in August (53.3mm), soil moisture

levels throughout the project area were increased significantly, masking any differences in soil moisture that may have been present. Even at the lowest irrigation level (50mm), moisture levels in the root zone were close to field capacity (Figure #1). Applying 100 and 150 mm of water brought the root zone in all cases to field capacity. The dryland sites averaged 71% of available moisture in the cultivated plots and 85% of available moisture in the stubble plots.

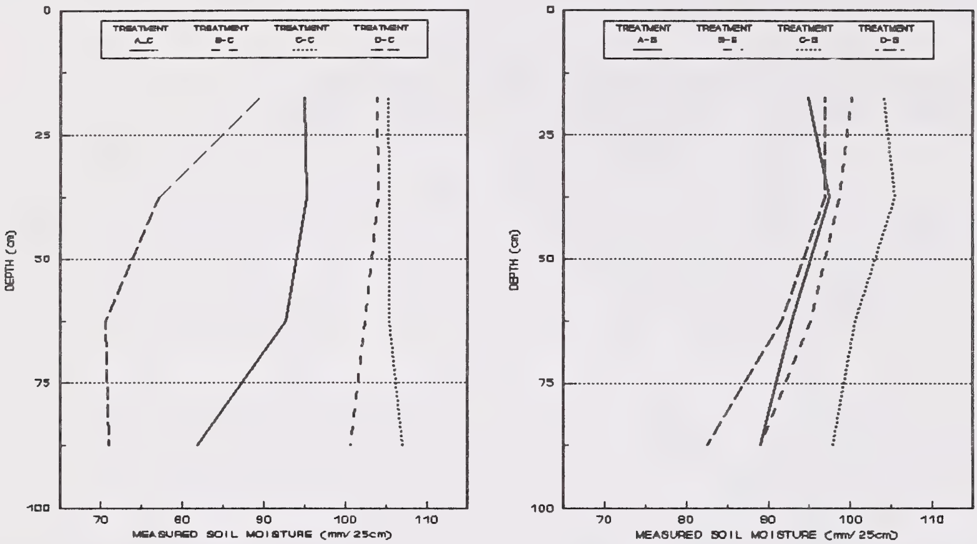

Figure 2: Fall Soil Moisture Levels.

In all by one instance, increasing fall irrigation application amounts brought about higher spring soil moisture levels with depth (Figure #2) for the cultivated and stubble plots.

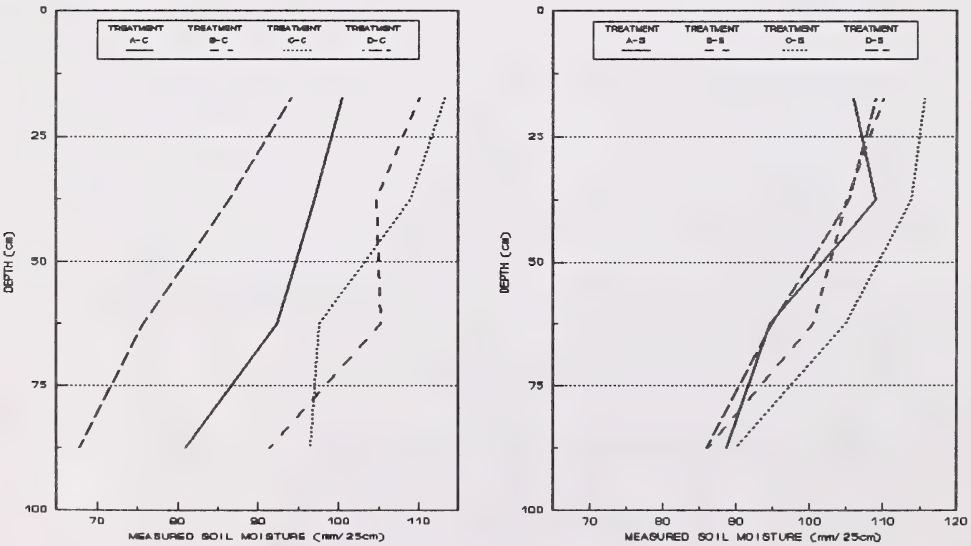

Figure 3: Spring Soil Moisture Levels.

Treatments A-C and B-C had 80.6% and 78.6% of the applied fall irrigation remaining within the 0-100cm zone at spring seeding. Overwinter monitoring indicated that Treatment A-C increased 6.3mm and Treatment B-C decreased 5.4mm. Treatment C-C had 83% of the applied fall irrigation remaining on April 1 and had a net loss of 9.5mm for the one meter depth. The 100 mm and 150 mm applications of water for treatments B-C and C-C resulted in irrigation water penetrating the 75-100 cm depth. However, only treatment C had measured downward movement of water below the 0-100 cm zone. 3.1mm or 2.1% of the applied irrigation amount was found in the 100-150 cm depth in the spring. Treatments A-C and B-C displayed no measurable downward movement of water past the 75-100 cm depth.

Seasonal evaporative losses also increased as fall irrigation amounts increased. Treatments A-C, B-C and C-C had a total loss of soil moisture of 94.4mm, 106.1mm and 113.3mm respectively. The total loss of soil moisture includes 100.7mm of overwinter precipitation.

Of the treatments in the stubble covered section, only treatment C-S, which received 150 mm of fall irrigation application, showed significant gain of soil moisture with depth over the other treatments (Figure #2).

Treatments A-S, B-S and C-S had 93.8%, 91.8% and 92.7% of the applied fall irrigation remaining within the 0-100 cm zone at spring seeding. Overwinter soil moisture levels increased, 23.9 mm, 18.8mm and 16.1mm for A-S, B-S and C-S respectively. The 100 mm and 150 mm applications of water for B-S and C-S resulted in water movement below the 0-100 cm zone. 9.3mm or 9.3% and 7.2mm or 4.8% of the applied fall irrigation amount was found in the 100-150 cm depth in the spring for treatments B-S and C-S.

Due to the movement of fall irrigation moisture into the 100-150 cm level for treatment B-S, seasonal evaporative losses varied as fall irrigation amounts increased. Treatments A-S, B-S and C-S had a total moisture loss of soil moisture for 76.8mm, 72.6mm and 91.8mm respectively. The total loss of soil moisture includes 100.7 mm of overwinter precipitation.

The amount of water lost on a daily basis between irrigation treatments varied from 0.53mm/day (Treatment A-C) to 0.62mm/day for Treatment C-C. Under stubble conditions, the amount of water lost between irrigation treatments varied from 0.43mm/day (A-C) to 0.47mm/day (C-C). The amount of water lost under cultivated conditions varied from 19% to 24% greater than stubble. The non-irrigated site had 13% greater water loss under cultivated conditions versus stubble.

SUMMARY AND CONCLUSIONS

This was the second year of the study. Precipitation of 100.7 mm for the overwinter interval was near the seasonal average of 116.6 mm.

All levels of fall irrigation on both cultivated and stubble sites showed soil moisture benefits in the spring. Treatment A increased spring moisture in the top 3/4 metre. Treatments B and C raised moisture levels throughout the entire one metre zone. Treatment C was the only treatment on a cultivated site to lose water to deep percolation.

In the stubble section of the trial all treatments raised spring moisture levels within the entire one metre zone. Treatments B-S and C-S both lost water to deep percolation. Treatment C-S was the only stubble-site treatment to demonstrate significant additional spring moisture benefits over the other treatments.

ELIMINATION OF AQUATIC WEEDS IN IRRIGATION CANALS USING TRIPLOID GRASS CARP FINAL REPORT

S. Jonas and E.D. Lloyd[11]

INTRODUCTION

In 1988, a five-year research study was initiated by the Committee on Biological Control of Aquatic Vegetation (CBCAV)[12] to study the use of a herbivorous fish (triploid grass carp, also called the white amur) to control aquatic vegetation in irrigation canals. Aquatic weeds are a major problem in many of the 8000 km of open canal systems in southern Alberta. Dense stands of aquatic vegetation can cause major operational problems in irrigation canals, restricting flows and reducing the capacity of canals by as much as 80%.

During the operational season, chemical treatment of canals is the only cost-effective method available to the irrigation districts for the control of aquatic vegetation. Removal of vegetation by mechanical means is very costly, and is difficult when there is water in the system. In many countries, grass carp have been imported and utilized as a biological control agent of aquatic vegetation. Triploid grass carp have not previously been studied in Canada for the management of aquatic vegetation.

In the spring of 1988, approximately 5000 six-day-old triploid grass carp larval fry were air shipped from the Lee County Hyacinth Control District (Fort Myers, Florida) to Edmonton. For the next 13 months, these fish were reared in the indoor quarantine facility of the Alberta Environmental Centre in Vegreville. In the spring of 1990, another 3000 larval fry were imported. All fish in both importations were reared, ploidy-tested, and screened for diseases.

Grass carp, which are native to the Amur River in China and the former Soviet Union, are one of the largest members of the minnow family (Cyprinids). They can be distinguished from other cyprinids by their large scales (about 38-44 along the lateral line), short dorsal fin (8-10 rays) inserted slightly ahead of the pelvic fins, and the absence of barbels. They have two rows of pharyngeal teeth, 2,5,5,2 or 2,5,4,2. In their native environment, they have obtained weights of 45 kg and a length over one metre.

Although they are members of the same cyprinid family as common carp (*Cyprinus carpio*), grass carp are not similar. Common carp were introduced to North America in the middle to late 1800s. They are readily differentiated from grass carp by their two pairs of conspicuous barbels about the mouth, the sucker-like mouth, 18-20 rays preceded by a spinous ray in the long dorsal fin, and five anal fin rays preceded by a strong toothed spine. Their feeding habits greatly increase the turbidity of water as they root in bottom sediments.

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[11] Vice-Chairman and Chairman of CBCAV, Irrigation Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Alberta, T1J 4C7.

[12] CBCAV inter-agency committee consisting of representatives from Alberta Agriculture, Food and Rural Development, Alberta Environmental Protection, Agriculture Canada, Alberta Irrigation Projects Association, and the Lethbridge Community College was established in 1987.

Grass carp are open-water feeders, spending most of their feeding time in the upper half of the water column. Vegetation is grazed downward by grass carp, and thus, they do not cause sediment disturbance and turbidity.

Concern about the possible deleterious impact that reproduction of grass carp could have on aquatic ecosystems has curtailed research on this species in Canada. Production of sterile fish at an economical cost was not possible until the pressure shock method was developed. The triploid condition is induced by hydrostatic pressure-shock of fertilized carp eggs, which results in retention of three chromosome complements. Theoretically, triploid cyprinids are sterile, and recent information suggests that triploid grass carp are functionally sterile. Although it is highly useful, the pressure shock treatment is rarely 100% successful. Therefore, the CBCAV implemented the Coulter Counter and Channelyzer method to examine and certify each individual fish before it was utilized in the study. All diploid fingerlings detected by this method were destroyed. For the determination of ploidy, the Coulter Counter method provides a rapid, accurate method that is not dependent on age, health or nutritional status.

Objective

The objective of the five-year cooperative research project was to study the utilization of sterile triploid grass carp *(Ctenopharyngodon idella)* to provide an overall biological control of aquatic vegetation in the canal systems of Alberta.

METHODS

The research project because of its broad nature and scope was divided into 17 major tasks. Each task was headed by professional(s). The CBCAV as a whole was responsible for the overall project management and budgeting.

It is beyond the scope and space provided for this summary report to discuss each task individually. Although inter-related, the tasks have their own specific objective(s), methods, conclusion(s) and recommendation(s). Interested readers are encouraged to obtain a copy of the final report or its relevant sections from the CBCAV.

For general information the following is a list of tasks.

List of Tasks

1. Canal Stocking, Monitoring and Recovery.
2. Growth and Survival in Dugouts.
3. Indoor Rearing.
4. Diagnostic Pathology.
5. Health Status of Imported Fish.
6. Efficacy Studies.
7. Predatory Fish.
8. Containment.
9. Water Temperatures.
10. Chilodonella Infection.
11. Sodium Treatment for Chilodonellosis.
12. Feeding Preferences.

13. Ploidy determination.
14. Quarantine Program.
15. Grass Carp/Rainbow in Dugouts.
16. Brood Fish.
17. Risk Assessment.

DISCUSSION SUMMARY

- Triploid grass carp are able to survive and overwinter at this northerly latitude.

- Grass carp effectively removed aquatic vegetation from heavily aquatic, weed- infested test reaches of canal.

RECOMMENDATION SUMMARY

Before any consideration of licensing grass carp for use in Alberta canals is given, the CBCAV recommends that the following additional studies need to be undertaken:

- Complete a full risk assessment.

- Generate a fish size/density stocking model based on temperature profiles of canals, densities of aquatic weed biomass, and composition of plant species.

- Research the potential for hormone-induced spawning.

- Identify the threshold thermal regimes required to successfully rear larvae and fry in outdoor summer and wintering ponds.

- Provide an estimate of the economic feasibility of the use of triploid grass carp in canal environments.

- Provide an estimate of the economic feasibility of the use of grass carp in other agriculturally-related environments.

IRRIGATION BLOCK STUDY

Jack Ganesh, P.Eng. and Bob Riewe, P.Ag.[13]

INTRODUCTION

In May 1990, Alberta announced a water management policy for the South Saskatchewan River basin which established guidelines for irrigation expansion. The announcement also stated that "these guidelines for limiting irrigation expansion would be reviewed in the year 2000." In order to make proper water management decisions, accurate and complete information regarding water supply, crop water use, and return flow databases for the irrigation districts is required.

The current review process of the Water Resources Act has highlighted many policy issues with potential implications for water management within the Irrigation Districts. This new water management policy reflects the increasing pressure on the resource. Irrigation water use is the largest licensed use of water in the Province and is often perceived by the public and many policy makers to be wasteful and beneficial only to a small group of people. In reality, the benefits are more general to the province and the country as a whole.

The objectives of the study involve four components:

1. To collect field data to calibrate the Irrigation District Model for an irrigation block within the BRID at the present level of on-farm and district management.
2. To test the accuracy of the Irrigation District Model (I.D.M.) as presently calibrated against actual field data collected for an irrigation block.
3. From the detailed block study, evaluate the irrigation district's present water allocation criteria.
4. Develop and test new management strategies to manage inflow, reduce return flows and improve on-farm use.

Project Location:

The Irrigation Block selected is located approximately 15 km. northwest of the Town of Vauxhall in the Bow River Irrigation District. The block selected is known as K-5 which was completely rehabilitated in 1991. The laterals are PVC-lined with gravel armour, new farm turnout structures and new check and drop structures.

This block is 3560 acres in size, made up of 1812 acres (50.9%) of surface irrigation (primarily border dyke), and 1748 acres (49.1%) sprinkler irrigation. The area being irrigated by sprinklers is made up of 849 acres (48.6%) of centre pivots and 899 acres (51.4%) of side wheel roll.

METHODS

In the spring of 1993, stilling wells were installed in key locations on the laterals and

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drains to monitor inflow and outflow in the laterals and outflow from the gravity irrigated fields. Because funding for the project was delayed, only 9 stilling wells were monitored using data loggers on hand from previous projects. This allowed monitoring of keys points within the block to identify potential problem areas. In reviewing the data collected from the various wells, it was determined that three stations were not operating correctly. One station will be relocated and two stations will have steel plates installed on the drop structures to make their crest more effective for water measurement.

Steel plates were installed on 3 drop structures located on drains. These plates form "V" Notch weirs up to a depth of 1 foot and a combination "V" Notch and Rectangular Weir for higher flows. With the flow of water in drains very small for most of the crop growing season, the "V" Notch will ensure a high level of accuracy. Higher flows can be accommodated by the combination "V" Notch and Rectangular weirs, ensuring high accuracy.

Cutthroat Flumes were designed by the Irrigation Branch and built by B.R.I.D. staff. Two Cutthroat flumes were installed in the spring of 1993 in farm head ditches. One flume was checked against the Pygmy Current Meter during the irrigation season. The results of the two methods were very close. In the fall of 1993, a total of 11 flumes were installed. Six more flumes are to be installed in the spring of 1994 . In total, 17 flumes will be installed to monitor flow in farm head ditches. For each Cutthroat flume installed, two stilling wells have also been installed. These wells are required to measure the height of water entering and leaving the flume.

Propeller flow meters have been installed on 8 of 10 sprinkler systems. The other two will be installed in the spring of 1994.

An automated weather station has been set up in the centre of the project area to collect temperature, solar radiation, rainfall, relative humidity and wind travel data.

RESULTS

The information being presented here is data that has been taken directly from ditchrider records. No other field data will be presented.

The major crops grown in the project area are cereals and forages. Cereals account for 61.6% and forages 16% of the total acres. Figure #1 gives the breakdown on a percentage basis for crops grown in the project area.

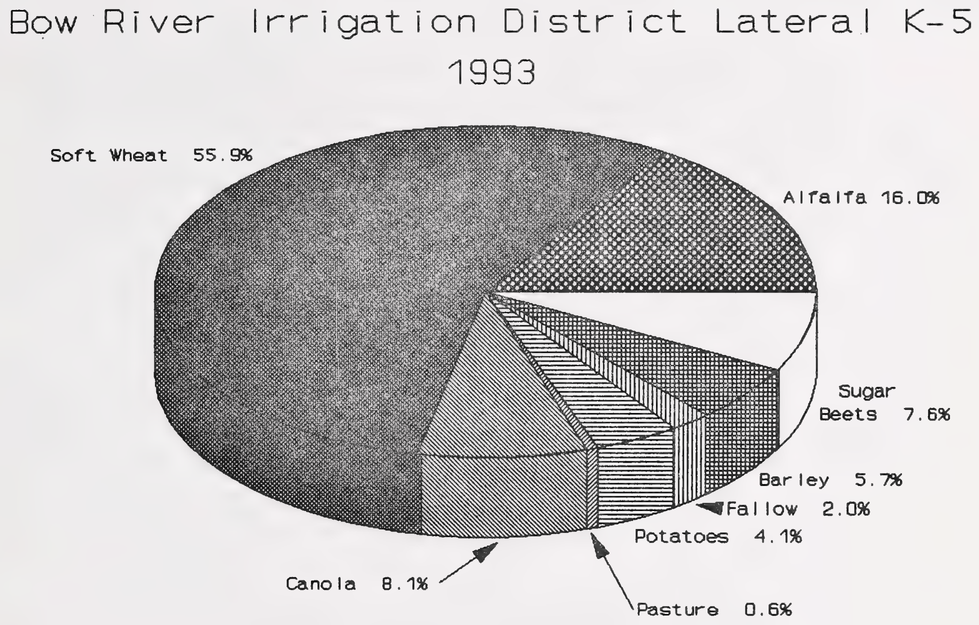

Figure #1: Crop Distribution

Up to the end of September, 287 mm of rainfall had been recorded for the area. The 30-year average for the Vauxhall area is 233 mm. Even with the above normal amounts of rainfall received in the area, a considerable amount of irrigation water was applied in 1993. Tables #1 and #2 outline the number of irrigations and the average amount of irrigation water applied.

In 1993, the Irrigation District diverted 4285 acre-feet of water into the block. With only a portion of the drains having data loggers to record the flow, no true value can be given on the amount of water being spilled by the District.

In 1993, ditchrider records indicated that on an average, sprinkler irrigated fields received 2.5 cubic feet per second (cfs) per turnout, whereas gravity irrigated fields received 5 cfs per turnout.

1993 was a year in which there was a greater need to get rid of water rather than apply it on the fields.

Table #1: Number of Irrigations.

CROP	GRAVITY IRRIGATED	SPRINKLER IRRIGATED	
		SIDE WHEEL	CENTRE PIVOT
SUGAR BEETS	1	4	-
POTATOES	-	-	7
SOFT WHEAT	1	2	2
CANOLA	-	2	3
BARLEY	1	1	-
ALFALFA	2	3	2
PASTURE	1	-	-

Table #2: Gross Amount of Irrigation Water Applied (mm)

CROP	GRAVITY IRRIGATED	SPRINKLER IRRIGATED	
		SIDE WHEEL	CENTRE PIVOT
SUGAR BEETS	178	-	-
POTATOES	-	-	305
SOFT WHEAT	229	305	178
CANOLA	-	229	152
BARLEY	229	203	-
ALFALFA	508	483	178
PASTURE	-	-	-

IRRIGATION - PRODUCTION

IRRIGATION MANAGEMENT OF TIMOTHY HAY - 1993

Roger Hohm P. Ag., Gregg Dill P. Eng., Elved Hughes[14]

INTRODUCTION

In the spring of 1993 a study was initiated to determine the water use characteristic of timothy hay. This study was coordinated by the Irrigation Branch of Alberta Agriculture Food & Rural Development in cooperation with Wilber-Ellis and 23 producers. Reliable figures on the consumptive use of timothy are not available for this area. Local information on the timing and rate of irrigation are also not available.

The study objectives of this first year were:

1) to evaluate present irrigation practices of timothy hay production
2) to develop a broad range of irrigation management ideas for timothy hay production

Timothy hay is increasing in popularity as a cash crop choice for irrigation farmers in southern Alberta. Current market demand is strong and indications are this demand will increase. With prices in the range of $100 - $140 per tonne, timothy production acreage is increasing rapidly.

METHODS

Wilbur-Ellis provided a list of current timothy hay producers in the area and twenty-three fields were selected for monitoring based on farmer interest. Two sites were abandoned due to poor plant population and two sites were seeded too late to be monitored. A map of the study area is included in the appendix.

Chemical and mechanical analysis were done on one soil sample from each field. A one metre neutron probe access tube was installed at each field and soil moisture monitored in 25 cm increments. A rain gauge was installed adjacent to each tube to measure precipitation and irrigation. Canola oil was added to each gauge to prevent evaporation.

Moisture and stage of growth were monitored and recorded weekly. Rooting depth was recorded until June 21 by visually examining core samples. Producers chose their own irrigation regime. Monitoring commenced on May 12, 1993 and concluded by September 17, 1993.

RESULTS

During this first year a lack of basic information was identified. Questions raised include:

1) How suitable is timothy to the irrigated areas of southern Alberta?
2) What yields can be expected and what are the agronomic inputs required?

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[14]Irrigation Branch, Irrigation & Resource Management Division, Alberta Agriculture, Food & Rural Development, Agriculture Centre, Lethbridge, Alberta T1J 4C7.

3) How much water is required for maximum crop production and when are the critical water use periods?

Due to the abnormally cold and wet growing season in 1993, the data collected was not used to estimate moisture requirements. Abnormally high water tables made it impossible to identify where the measured moisture came from. Much moisture was lost to deep percolation which was not measured. Harvesting was delayed in most fields and actual yields were difficult to estimate. Table 1 shows the historical mean values and actual 1993 values for precipitation and temperature at the Lethbridge Research Station.

Table 1. Historical and 1993 weather data

	PRECIPITATION (mm)		TEMPERATURE (°C)	
Month	1993 Mean	Historical	1993 Mean	Historical
May	45	54	12.9	10.8
June	117	72	13.8	15.0
July	126	42	14.4	18.1
August	64	44	15.0	17.0
September	65	27	10.1	12.0
Total/Ave	417	238	13.2	14.6

The date each field reached various growth stages was recorded. The average dates are shown in Table 2.

Table 2. Average dates of growth stages

GROWTH STAGE	MEAN DATE
6-leaf	May 24
Boot	June 8
Head	June 21
Flower	July 12
First Cut	July 21

Because the first cut was delayed for most fields, many of the shoots that would have

produced heads for the second cut were already developed. They were removed with the initial harvest, consequently second cut heads were sparse.

Maximum root development reached a depth of 90 to 110 cm by June 15. This was midway between the boot stage and the full head stage. Although roots were found deeper the majority were found in the top 25 cm.

DISCUSSION

1. Water table wells should be installed at each site to determine if ground water is entering the monitored zone.
2. Moisture should be monitored to a depth of 1.5 metres to allow for moisture monitoring below the one metre root zone. Moisture lost to deep percolation could then be determined.
3. Monitoring should commence by April 15 and continue until after the second cut is taken.
4. Precipitation and irrigation should be differentiated by installing a second rain gauge outside the irrigated area.
5. Readings should be performed twice a week, if possible. Critical moisture use stages would be more apparent with this monitoring regime.

CONCLUSION

As a result of the poor crop year no data was analyzed. The year was used to develop a strategy to collect data more intensively to develop consumptive use curves for timothy.

FORAGE PRODUCTION ON IRRIGATED CHERNOZEMIC AND SOLONETZIC SOILS IN THE BERRY CREEK BASIN (YEAR THREE-1993)

G.M. Greenlee, T.M. Peters, P.D. Lund and D.R. Bennett[15]

INTRODUCTION

The objectives of this four-year study in the Berry Creek Basin are:

1) To determine the forage production capability of two Solonetzic and two Chernozemic soil associations under three levels of irrigation.

2) To assess changes in soil salinity and sodicity in these soils resulting from the three different levels of irrigation.

3) To evaluate the irrigation suitability of the irrigated Solonetzic soils in light of the irrigation management regimes implemented.

This progress report contains a brief summary of results from monitoring conducted in 1993. A summary of results from 1992 monitoring is given in Greenlee et al. (1993).

METHODS

Background

Four study sites in the Berry Creek Basin of east-central Alberta were selected for this project in the summer of 1990. Two study sites consist of dominantly Solonetzic soils (Weich site near Hanna and Blair site near Sheerness) and the other two sites (McNiven and Sunstrum near Cessford) have mainly Brown Chernozemic soils. The Solonetzic sites are adjacent to relatively large Ducks Unlimited reservoirs, and the Chernozemic sites are adjacent to Berry Creek.

Each study site consists of a rectangular field approximately 55 m wide by 340 m long. Four seasonal treatments, representing three target levels of irrigation-200, 300 and 400 mm, and a dryland control-were replicated three times within each study site. Each replicate of each treatment (plot), is approximately 55 m long by 18 m wide and each study site has 12 plots. The plots are separated by 9-m wide buffer strips.

Ten soil profiles per plot were characterized and sampled in the fall of 1990 along two parallel transects (five soil profiles per transect) situated 5 m from the side of each plot and starting 10.4 m from the end of the plot. Each profile was sampled according to horizons, with representative samples taken from the A and B horizons and from the upper and lower C horizons to a depth of 1.2 m. Soil samples were analyzed for pH, electrical conductivity (ECe) and soluble cations of the saturation paste extract (Rhoades 1982). The sodium adsorption ratio (SAR) was also calculated.

One water table well and two 1.5 m long neutron probe access tubes were placed within each plot to monitor shallow water table fluctuations and soil moisture content in response to irrigation events and precipitation. Soil moisture content in the 400 mm treatments was used to schedule irrigations. Irrigations were carried out whenever soil

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moisture content was more than 50 mm below field capacity. A datalogger and tipping-bucket rain gauge were used to record natural precipitation at each study site.

Plot mean values for crop yield were analyzed using an analysis of variance statistical model and a protected least significant difference test. A split-plot analysis of variance, with time as the split, and protected least significant difference test were conducted for each soil chemical parameter to determine whether significant changes in ECe and SAR had occurred from 1990 to 1993 within each sampling depth at each site. Box's conservative F-test (Box 1954) was used to test the significance of the year and year by treatment effects since years could not be randomized in this study. Tukey's studentized range test was used to compare mean values for each treatment from 1990 to 1993 when the year by treatment interaction was significant in the analysis of variance.

<u>Cropping, Irrigation and Monitoring</u>

Initial site preparation and cropping in 1991 were described by Bennett et al. (1992). Fertilizer was deep-banded into barley stubble at a rate of 336 kg ha^{-1} of 11-51-0 in the spring of 1992. Beaver alfalfa seed was inoculated with Rhizobium and direct-seeded at a rate of 12 kg ha^{-1} with a zero till truax drill. The alfalfa plots at each site were sprayed with sethoxydim (poast) in June at a rate of 19 L ha^{-1} to control volunteer barley. A solid-set irrigation system was installed on each irrigated plot and irrigation water was applied at a rate of 10 mm h^{-1} in increments of 20, 30 and 40 mm on the 200, 300 and 400 mm treatments, respectively. Irrigation events in 1993 ranged from only one at the Weich site to four at the other three sites due to the abnormally high levels of natural precipitation. This resulted in total applications ranging from 22, 36 and 55 mm for the 200, 300 and 400 mm treatments, respectively, at the Weich site to 86, 150 and 182 mm for the 200, 300 and 400 mm treatments, respectively, at the McNiven site (Figure 1). These were actual application amounts measured by rain gauges situated in the irrigated plots.

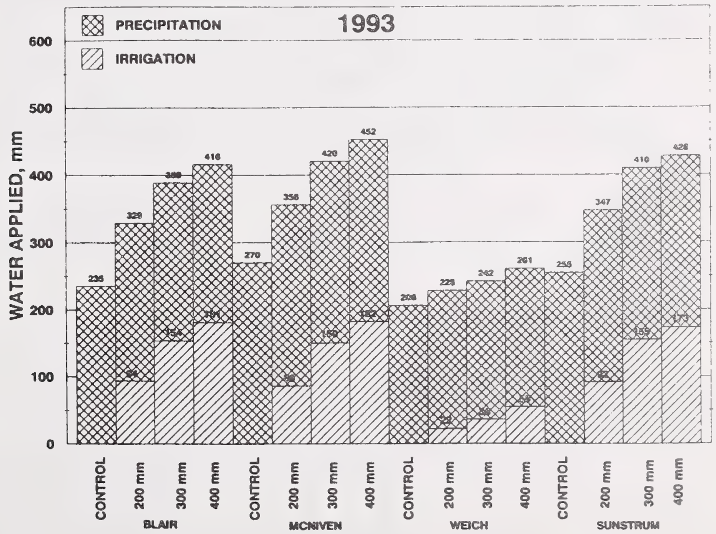

Figure 1. **Total water applied during the 1993 growing season at the four study sites.**

Alfalfa yields were determined by sampling alfalfa in two cuts during mid June and early August. Alfalfa was sampled by cutting a 2-ft swath adjacent to each soil sampling transect, using a forage plot harvester. Soil samples were collected in the fall of 1993 from the same ten locations in each plot.

PRELIMINARY RESULTS AND DISCUSSION

Site Characteristics

Relative percentages of Solonetzic and Chernozemic soils that occur at each study site were indicated by Bennett et al. (1992). Statistical analyses of 1990 soil samples to assess the uniformity of treatments at each study site indicated that significant differences between treatments were not evident for any soil chemical parameter except for pH of the B horizon. The conclusion was that initial soil characteristics were reasonably uniform at each study site prior to irrigation.

Alfalfa Yield and Water Applied

The significance of differences in total dry matter (TDM) yield between treatments in 1993 (Table 1 and Fig. 2) indicates that a minimal response to irrigation was observed on the

Table 1. Comparison of mean alfalfa yield (oven dry weight) from each treatment in 1993

	Treatment[z]				
Site	Control	200 mm	300 mm	400 mm	Probability
	Total Dry Matter, t ha^{-1}				
Weich	2.64ab	2.36ab	2.98b	2.05a	$p < 0.01$
Blair	1.88a	3.79b	4.43b	4.50b	$p < 0.01$
McNiven	3.58a	6.20b	7.65bc	8.25c	$p < 0.05$
Sunstrum	3.00a	5.00b	5.80b	5.81b	$p < 0.01$

[z]Values for the treatments at each site followed by the same letter are not significantly different at $p < 0.01$ or $p < 0.05$, as determined by a protected least significant difference test.

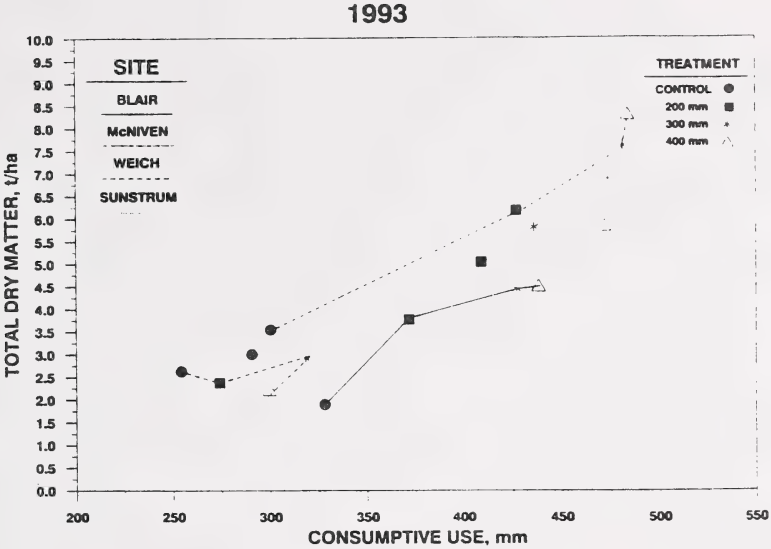

Figure 2. **Mean alfalfa yield on each treatment as related to consumptive use of natural precipitation and irrigation water applied in 1993.**

Weich Solonetzic study site. The only significant difference observed was between the 300 mm and 400 mm treatments, wherein the 400 mm treatment had the lowest of all treatment yields, including the dryland control. Abnormally high amounts of natural precipitation reduced the need for irrigation, and masked the treatment effects. The Weich site received 206 mm of precipitation, as compared to 235 mm at the Blair site, 270 mm at the McNiven site and 256 mm at the Sunstrum site. Normal precipitation amounts for the Berry Creek Basin from May 1 to the end of August range from about 180 to 200 mm.

Significant differences in TDM yield between the irrigation treatments and the dryland control were detected at the Blair Solonetzic study site, and at both Chernozemic sites. Yields were highest in the 400 mm treatments, but the only significant difference between irrigation treatments was between the 200 mm and 400 mm treatments at the McNiven Chernozemic site.

TDM yield was relatively low compared to yields reported elsewhere in southern Alberta (Bennett and Entz 1990). This may be attributed to the cool wet growing season experienced in 1993.

Changes in Soil Salinity and Sodicity

Statistically significant differences in soil salinity and sodicity were evident within the A horizon of soils at each study site from 1990 to 1993 (Table 2). A significant increase in soil salinity was detected in the A horizon at each study site from 1990 to 1993 (Table 2), however no significant differences were observed between the irrigation treatments and the dryland control at the Weich and Blair study sites (Table 3). A significant increase was evident between the dryland control and the irrigation treatments at the McNiven study site, and a significant increase was detected from the dryland control and 200 mm treatments to

Table 2. Comparison of soil salinity and sodicity at the four study sites from 1990 to 1993[z]

Site	Horizon	EC, dS m^{-1} 1990	1991	1992	1993	Horizon	SAR 1990	1991	1992	1993
Weich	A	0.65b	0.76b	0.80b	1.29a	A	4.27b	5.05a	5.04a	4.15b
	B	2.74a	1.90b	2.17b	2.48a	B	10.91a	10.73a	10.68a	11.29a
	C1	5.95a	5.46a	5.33a	5.57a	C1	11.35a	11.89a	10.60b	11.22ab
	C2	7.58a	6.96b	6.81b	7.03b	C2	12.85a	12.47a	11.96a	12.38a
Blair	A	0.49b	0.75a	0.76a	0.82a	A[Y]	3.40	4.80	5.36	4.38
	B	3.55a	2.32b	2.57b	2.54b	B	12.05a	11.84a	11.32a	11.51a
	C1	6.75a	6.26a	5.90a	6.05a	C1	12.67a	12.87a	11.83a	12.07a
	C2	8.10a	7.46a	7.13a	7.40a	C2	14.33a	14.42a	13.34b	13.44b
McNiven	A	0.26d	0.71a	0.52c	0.62b	A[Y]	0.30	1.02	1.85	0.97
	B[Y]	0.28	0.39	0.56	0.49	B[Y]	0.62	0.70	0.88	1.22
	C1	0.56a	0.63a	0.70a	0.70a	C1	1.52a	1.51a	1.29a	1.25a
	C2	1.50a	1.22a	1.32a	1.28a	C2	2.09a	2.22a	1.96a	2.01a
Sunstrum	A	0.27c	0.68a	0.51b	0.68a	A[Y]	0.30	0.75	1.30	0.86
	B	0.43a	0.54a	0.52a	0.53a	B[Y]	0.56	0.62	0.64	0.89
	C1	0.62b	0.92a	0.83a	0.90a	C1	1.43a	1.46a	1.38a	1.41a
	C2	1.08b	1.41a	1.19b	1.35a	C2	2.90a	2.52a	2.43a	2.34a

[z]Where annual mean salinity and sodicity values for each horizon at each site followed by the same letter are not significantly different at $p < 0.05$.

[Y]Year by treatment interaction was significant at $p < 0.05$, see Figure 3.

Table 3. Comparison of soil salinity and sodicity between treatments at the four study sites[z]

Site	Horizon	EC, dS m^{-1} Control	200 mm	300 mm	400 mm	Horizon	SAR Control	200 mm	300 mm	400 mm
Weich	A	0.74a	0.85a	0.93a	0.99a	A	3.62a	4.44a	3.96a	6.50a
	B	2.18a	2.27a	2.24a	2.61a	B	9.36a	10.81a	10.44a	13.00a
	C1	5.13a	5.39a	5.76a	6.02a	C1	10.12a	11.42a	10.77a	12.75a
	C2	7.31a	6.59a	7.03a	7.46a	C2	12.37a	12.29a	11.87a	13.12a
Blair	A	0.58a	0.72a	0.79a	0.73a	A[Y]	3.36	4.94	4.44	5.20
	B	3.33a	2.79a	2.05a	2.80a	B	11.93a	12.14a	9.54a	13.12a
	C1	6.69a	6.53a	4.82a	6.91a	C1	11.78a	13.29a	10.81a	13.57a
	C2	7.36a	7.51a	6.64a	8.57a	C2	12.76a	14.79a	12.60a	15.39a
McNiven	A	0.38b	0.57a	0.56a	0.60a	A[Y]	0.28	1.12	1.34	1.40
	B[Y]	0.33	0.47	0.48	0.44	B[Y]	0.56	0.75	1.10	1.01
	C1	0.66a	0.68a	0.67a	0.58a	C1	1.28a	1.67a	1.52a	1.10a
	C2	0.97a	1.69a	1.56a	1.10a	C2	1.87a	2.50a	2.05a	1.87a
Sunstrum	A	0.44b	0.49b	0.59a	0.62a	A[Y]	0.25	0.82	1.00	1.12
	B	0.46a	0.58a	0.49a	0.49a	B[Y]	0.55	0.74	0.66	0.76
	C1	0.75a	0.92a	0.79a	0.80a	C1	1.50a	1.74a	1.22a	1.21a
	C2	1.18a	1.55a	1.21a	1.09a	C2	2.76a	3.06a	2.10a	2.27a

[z]Where treatment means for each horizon at each site followed by the same letter are not significantly different at $p < 0.05$.

[Y]Year by treatment interaction was significant at $p < 0.05$, see Figure 3.

the 300 and 400 mm treatments at the Sunstrum site (Table 3). Most A horizon EC values were below one at each study site. Significant year by treatment interactions were observed in soil salinity of the B horizon at the McNiven study site, in soil sodicity of the A horizon at the Blair site, and in soil sodicity of the A and B horizons at the McNiven and Sunstrum sites (Fig. 3). Salinity in the B horizon of soils in the irrigation treatments at the McNiven study site, sodicity in the A horizon of soils in the irrigation treatments at the Blair site, and sodicity in the A and B horizons of soils at the McNiven and Sunstrum sites have generally increased from 1990 to 1993 (Fig. 3). However, some of these differences were not statistically significant. Most A horizon SAR values were below six at the Weich and Blair study sites, and all were below two at the McNiven and Sunstrum sites.

A significant decrease in soil salinity was detected in the B horizon of soils at the Blair study site from 1990 to 1993 (Table 2). This same phenomenon was observed in the B horizon of soils at the Weich site from 1990 to 1992, however, a significant increase in soil salinity was apparent from 1992 to 1993 (Table 2). Significant changes in soil salinity and sodicity in the C1 and C2 horizons of soils from the different treatments were generally not observed from 1990 to 1993. Increases in soil salinity in surface horizons may reflect the new equilibrium being established in the soils due to the irrigation water quality (Fig. 4). Surface horizon EC values were all below one at the four study sites in 1993. The decrease in soil salinity in the B horizon of soils at the Blair study site from 1990 to 1993 may be due to leaching of salts by the abnormally high amounts of natural precipitation, in addition to the irrigation water applied. Additional monitoring will be done in 1994 to verify the trends observed from 1990 to 1993.

ACKNOWLEDGEMENTS

Gratitude is expressed to T. Ormann and J. Bakker for assistance with irrigation and monitoring activities. Gratitude is also extended to T. Entz, Agriculture Canada, for help with statistical analyses. Thanks are expressed to G. Weich, R. Blair, M. McNiven, J. Sunstrum and B. Sunstrum, co-operating farmers, for allowing access to land for this experiment. Thanks are also expressed to D. Quast, R. Landis, M. McNiven and B. Sunstrum for harvesting alfalfa at the study sites. Appreciation is extended to the Alberta Soils and Crops Horticultural Research Centre at Brooks for allowing use of their crop-drying ovens and crop-threshing facilities.

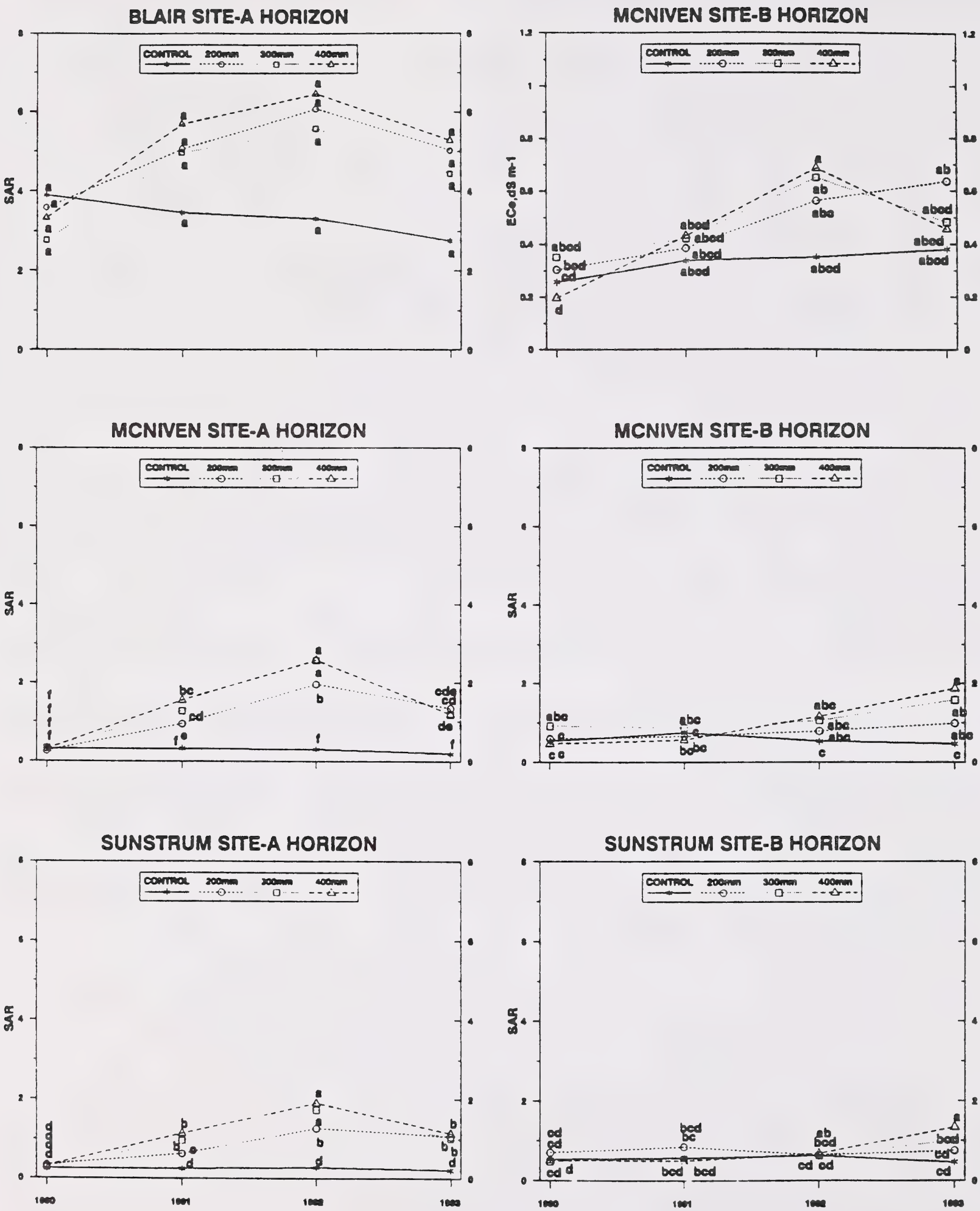

Figure 3. Comparison of soil horizon salinity and sodicity in each treatment at the three study sites which had a significant year by treatment interaction from 1990 to 1993 (mean values for each horizon at each site followed by the same letters are not significantly different at $p < 0.05$).

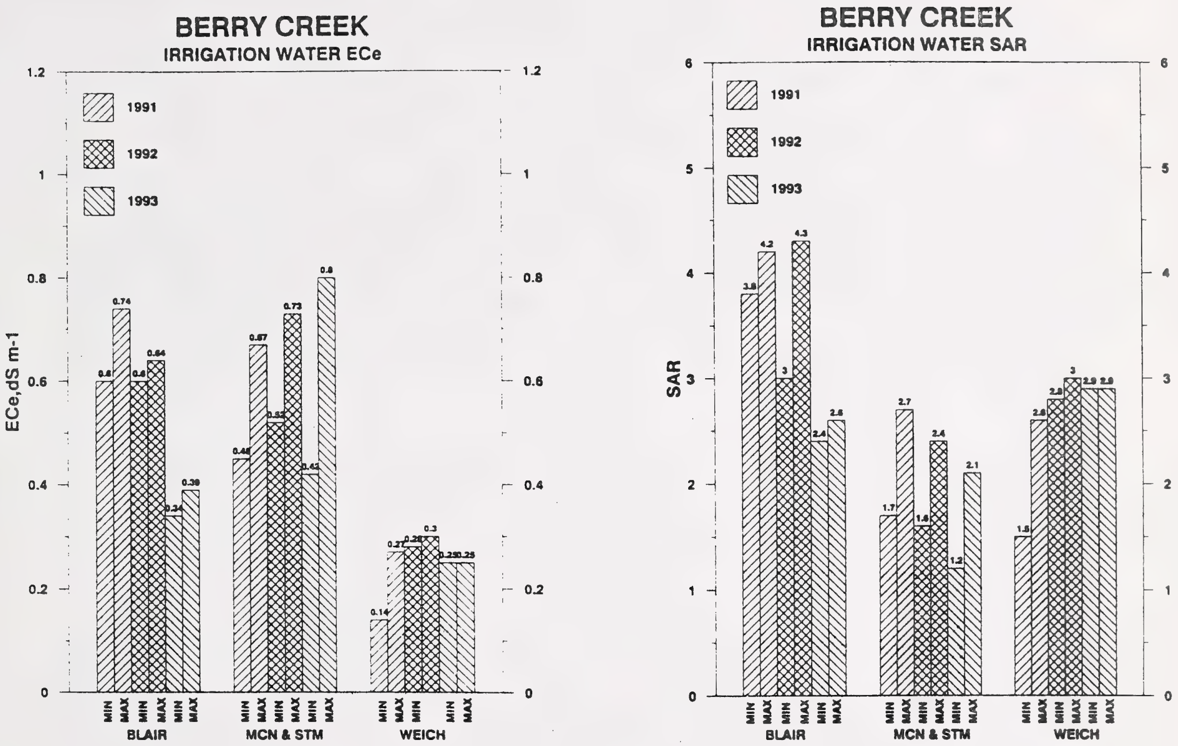

Figure 4. **ECe and SAR of water used to irrigate the four study sites from 1991 to 1993.**

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CONSUMPTIVE MOISTURE USE OF IRRIGATED ALFALFA - 1993 UPDATE

Robert Riewe, P.Ag. and Vincent Ellert[16]

INTRODUCTION

This report is an update on a project which commenced in 1992 and will continue through 1995. In order to properly manage the irrigation of alfalfa, it is important to know the daily consumptive use. Data that has been traditionally used in Alberta was developed several years ago by Agriculture Canada in Lethbridge. It is not fully understood how this data accounts for changes in crop uses caused by cutting. Multiple cuttings are necessary to obtain maximum economic yield. For these reasons, a study was initiated with the following objectives:

1) To determine the crop water use between cutting periods.
2) To verify current consumptive use data of alfalfa under normal field conditions.

METHODOLOGY

In consultation with local alfalfa growers, one representative site was selected in each of 13 fields. All stands of alfalfa were between two and three years old. One 2 metre long aluminum access tube was installed at each site. Soil moisture levels were measured by a neutron moisture probe (Campbell Pacific Model DR531). At the time the access tube was installed, soil samples were collected from each 25 cm increment for textural analyses.

Textural analyses were carried out using the Gee & Bauder method[3]. Field capacity and wilting point were determined by applying the formula developed by Oosterveld & Chang[5] to the texture of the soil. The neutron probe readings were converted to mm of water for comparison with field capacity and wilting point.

Irrigation management of the sites was at the discretion of the growers. Results of the neutron probe readings were provided to the growers.

Neutron probe readings were taken on a weekly basis starting May 12. Beginning with the first cutting, probe readings were taken three times a week (weather permitting), until mid October. Soil moisture readings were taken at 25 cm increments down to 2.0 m.

Other data recorded included rainfall and irrigation dates and amounts. The date, crop stage (% bloom, etc.) were also recorded during the field visits. Stand appearance, fertilization, and other cultural practices were recorded. Data analyses considered the moisture use between each field visit.

RESULTS

One of the sites used in 1992 was deleted from the project due to a deterioration in

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the crop stand and two other sites were plowed down after the second cutting.

The growing season was characterised by cool temperatures (Figure 1) and above average rainfall. The long term average May to September rainfall for Lethbridge is 250.5 mm.[2] The average rainfall received on all sites was 327 mm.

The average seasonal consumptive use of all 13 sites was 387 mm, with a range of 322 mm to 465 mm and a standard deviation of 43.9 mm (Figure 2). Seasonal consumptive use results were much lower than the average consumptive use figure of 680 mm per season determined by Agriculture Canada. Seasonal consumptive use predicted by the modified Jensen-Haise Equation was 717.0 mm. The large variance between field measured consumptive use, the results of the equation and field values reaffirms the need for continued research in this area.

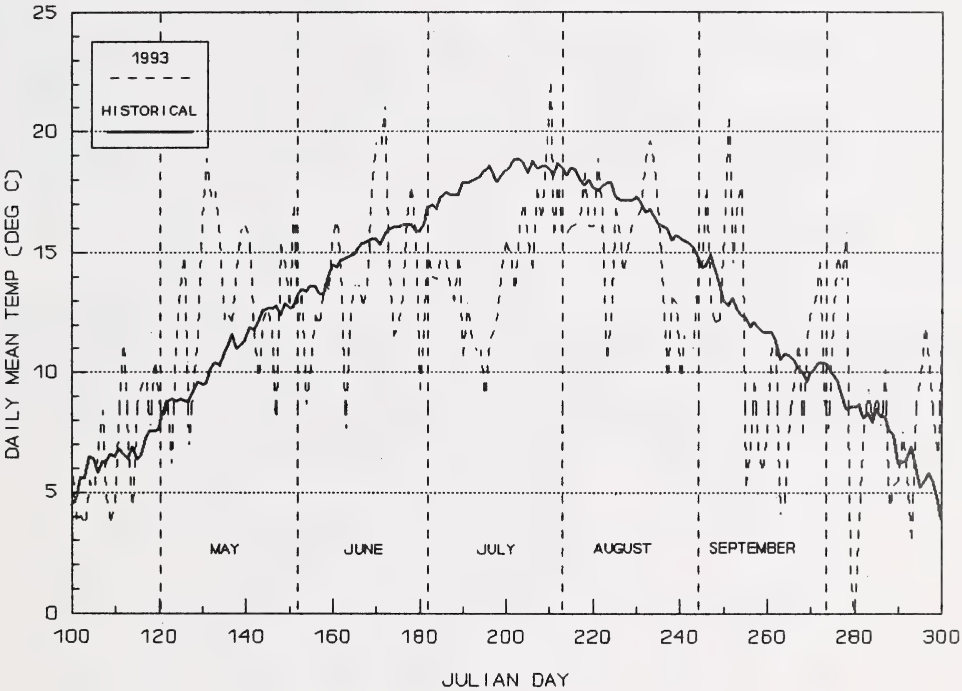

Figure 1 - Mean Daily Temperature - Lethbridge

The above average rainfall and reduced consumptive use allowed all growers to easily maintain the recommended minimum of 60% of available moisture. In many cases this was accomplished with only one irrigation (70-100 mm) early in the season.

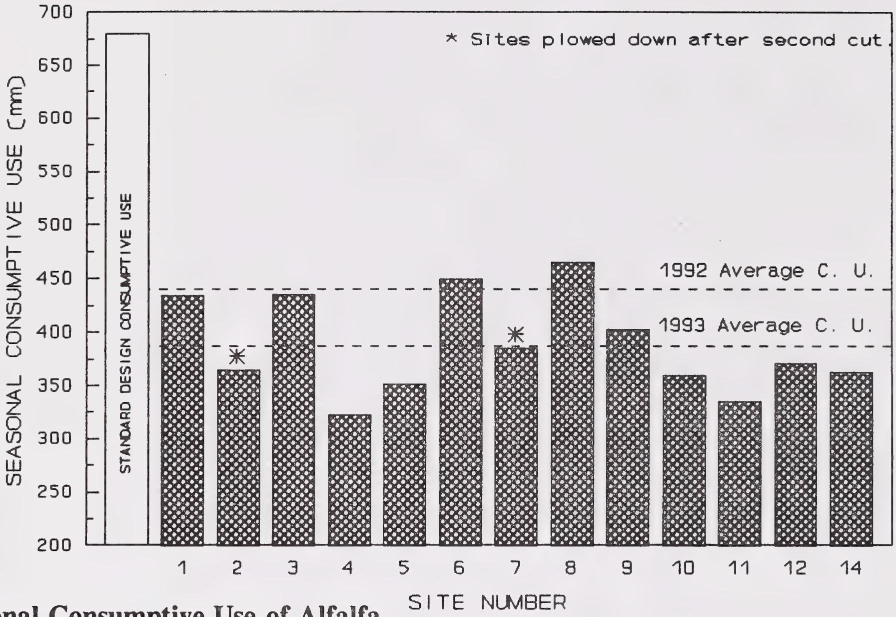

Figure 2: Seasonal Consumptive Use of Alfalfa

An example of a typical soil moisture curve is presented in Figure 3. Harvesting on most fields was frustrated and delayed due to the unusually cool and rainy weather (Figure 2). The period between swathing and removal of crop was as high as 24 days. Consumptive use for each quarter of the period between cutting dates was calculated; results were inconclusive due to the very irregular length of time between cuttings.

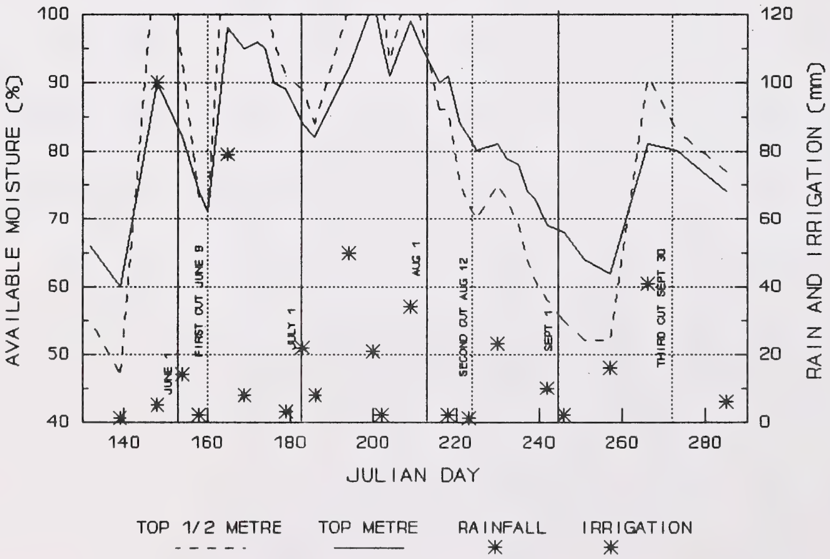

Figure 3: Available Moisture - Site #3

Some of the sites suffered from excess soil moisture. At two sites, irrigations of 140 mm were followed by 10 days of cool rainy weather with total rainfall of 75 mm. Consumptive use at these sites was very low for the two weeks following the irrigation. Unfortunately 1993 was not representative of a typical alfalfa production season. No results are presented here.

The initial plans were to complete this study in 1994. Due to the non-typical growing seasons in 1992 and 1993, it is now proposed that data from 1995, and perhaps 1996, will be required to form reliable conclusions.

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IRRIGATION SUITABILITY OF SOLONETZIC SOILS IN THE COUNTY OF NEWELL, ALBERTA

D. Rodney Bennett, T. Murray Peters and Phil D. Lund[17]

INTRODUCTION

Solonetzic soils are generally rated nonirrigable under existing land classification standards for irrigation (Alberta Agriculture 1983). Undesirable features include poor structural characteristics of the Solonetzic B horizon, high levels of subsoil salinity and sodicity, and extreme variability of soils in Solonetzic landscapes. A 5-yr study was conducted in the County of Newell from 1984 to 1988 to monitor soil salinity and sodicity, water-table levels and crop production on nine Solonetzic soil associations under normal irrigation management practices (Bennett and Entz 1990). Land classification standards were not modified by Irrigation Council to allow irrigation of Solonetzic soils as a result of this study. However, irrigation of the nine soil associations was continued to monitor changes in these soils over a longer period. The soil salinity and sodicity status of these soils in the tenth year of monitoring is hereby reported.

METHODS

The location of study sites, characteristics of the nine Solonetzic soil associations and monitoring activities have been described in detail previously (Bennett and Entz 1990). Soils were sampled in the fall of 1993 from five profiles at 10-m intervals along a random transect within each of the three plots at each site. Four samples were collected from each profile to represent the Ap, B and upper (C1) and lower (C2) C horizons to a depth of 1.2 m. Composite samples for each sampling depth were obtained by bulking samples from the five sampling locations. All soil samples were analyzed in the laboratory for soil reaction (pH), electrical conductivity (ECe), soluble cations (calcium, magnesium, sodium and potassium) and calculation of the sodium adsorption ratio (SAR) of the saturated paste extract (Rhoades 1982).

Split-plot analysis of variance (split by time) and protected least significant difference tests (Gomez and Gomez 1984) were performed on pH, ECe and SAR values from each plot to determine whether or not significant changes had occurred within each sampling depth from 1983 to 1993. A logarithmic transformation was applied to ECe and SAR data prior to analyses and Box's conservative F-test (Box 1954) was used to test the significance of the year and site-by-year effects since years could not be randomized in the study. Only results from the composite sampling conducted in 1988 are reported, since statistical results from 1988 composite and individual profile sampling were similar.

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RESULTS AND DISCUSSION

Soil salinity and sodicity

The site by year interaction in the split-plot analyses of variance test was not significant for pH, ECe and SAR in any of the four horizons, allowing differences over time to be interpreted independently (Table 1). A statistically significant increase in pH was evident in the A and B horizons during the first three to four years of monitoring. This increase may be attributed to the relatively high pH of the irrigation water (Bennett and Entz 1990) and to the increased biological activity associated with irrigated crop production (Amundson and Lund 1987).

Table 1. Annual mean pH, ECe and SAR values at all nine sites from 1983 to 1993

Parameter	Horizon	1983	1984	1985	1986	1987	1988	1993	LSD
pH	A	6.32d	6.88c	7.06bc	7.32ab	7.44a	7.46a	7.39a	0.274
	B	7.35e	7.50de	7.55cd	7.59bcd	7.79a	7.75ab	7.70abc	0.190
	C1	8.14a	7.87bc	7.77c	8.01ab	7.94b	7.97b	7.93b	0.150
	C2	8.12a	7.93cd	7.87d	8.09ab	7.98bcd	8.01abc	8.02abc	0.119
ECe, dS m^{-1}	A	1.92ab	1.37c	1.51bc	2.33a	1.93ab	1.20c	1.99ab	0.509
	B	3.30	2.13	3.52	2.84	2.68	2.76	3.28	NS
	C1	7.67	6.45	6.01	6.31	6.05	6.02	5.57	NS
	C2	8.83	8.28	7.22	8.18	7.78	8.62	7.47	NS
SAR	A	2.41bc	1.83c	2.94b	3.12b	4.13a	2.81b	3.14b	0.894
	B	7.64	5.33	5.60	5.98	6.68	6.27	6.84	NS
	C1	10.50	9.10	8.30	9.08	8.98	10.38	10.22	NS
	C2	12.85	12.44	10.28	12.12	11.56	13.07	13.11	NS

a-e Means within each row followed by the same letter are not significantly different ($p < 0.05$).

A significant difference between years was observed for ECe and SAR values in the A horizon, however, a trend over time was not evident (Table 1). Differences between years were not significant for ECe and SAR in the B, C1 and C2 horizons. Thus, the salt status of all nine Solonetzic soil associations has remained about the same over the 10-yr monitoring period.

CONCLUSION

Inasmuch as soil salinity and sodicity levels have not shown significant change during the 10-yr monitoring period, revision of land classification standards to allow irrigation of Solonetzic soils is not recommended. Land units dominated by Solonetzic soils require very careful irrigation and fertilizer management to compensate for the limitations of these soils. The relatively low productive capability and high degree of variability in yield greatly increase the risk related to irrigated crop production, therefore, limited water supplies would be better used on more productive land.

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CONSERVATION - CROPPING AND TILLAGE

SUSTAINABLE CROPPING SYSTEMS RESEARCH STUDY
THREE HILLS SITE

E. Oosterhuis and T. L. Jensen[18]

INTRODUCTION

In Alberta, crop rotation effects on yields and field productivity, have received a great deal of attention. Long-term rotational studies by Agriculture Canada and University of Alberta research scientists began early in this century. These studies are located at the Lethbridge Research Station (Dark Brown soil zone), for Agriculture Canada, and at the Ellerslie (Black soil zone) and Breton (Gray soil zone) research farms for the University of Alberta. In 1991 work began on two new crop rotation studies, one located at Bow Island (Brown soil zone) and this one at Three Hills (Dark Brown - Black transition soil zone).

The objectives of this study are as follows:

1. Evaluate the long-term effects of various cropping systems (crops and crop rotations) on the productivity of the soils at the site. These rotations represent cropping systems that farm managers presently use or could use in this area.
2. Use the information gathered to help farm managers decide what cropping systems would be suitable on their farms where similar soil - climatic conditions exist.
3. Compare the results of this research site with results from the other 5 sites mentioned above. The experimental design includes appropriate crops and rotations as well as replicated and randomly assigned treatments so that the data from this site can be combined with and analyzed along with the data from the other sites.

METHODS

This long-term rotational study, located next to the Three Hills airport , is a 10 acre site of provincially owned land in the M.D. of Kneehills.

The experimental design consists of 20 main plots per each of the 4 replicate blocks. The 20 main plots are randomly assigned and each represents a specific phase of one of the 9 specific crop rotations assessed in the study. All crop rotations and fertilizer treatments were reviewed and selected with assistance from other members of the sustainable cropping systems committee. The 9 crop rotations are as follows:

1. Continuous wheat
2. Wheat - canola - barley - peas
3. Fallow - wheat
4. Green manure (peas) - wheat
5. Fallow - wheat - wheat
6. Fallow - peas - wheat
7. Continuous grass (brome) as a forage crop
8. Continuous alfalfa and grass (brome) as a forage crop

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9. Fall rye - wheat - peas and oats silage

Each block is split by 5 fertilizer treatments as follows:

a. Manure (at a rate of 6 tonne per hectare)
b. Nitrogen plus phosphorous (at a rate of 60 kg N and 30 kg P per hectare)
c. Nitrogen only (at a rate of 60 kg N per hectare)
d. Phosphorous only (at a rate of 30 kg P per hectare)
e. No fertilizer

RESULTS AND DISCUSSION

This experiment began in the spring of 1991. During the fall of 1990 the site was treated with a trifluralin herbicide, therefore the first year consisted of the entire site being seeded to a cover crop of canola. Random samples were taken during the fall of 1991 and a uniformity test was carried out. These results enabled proper orientation of the research plots and the long-term rotations were started in the spring of 1992. Unfortunately an early snowfall in the fall prevented proper maturation of the crops and yield data was distorted for 1992. The second year of this rotational study, 1993, was a successful year as growing conditions were suitable for proper crop growth, and yield data was collected as planned.

All sampling for 1993 was carried out as planned. In addition to the regular soil sampling, several deep cores were taken during the first week of November. These deep cores were taken for a Nitrate Leaching study funded by the CAESA Water Quality Committee. The project manager for this study is Dr. Barry Olson. The Sampling was performed by Curt Livergood from the Conservation and Development Branch in Lethbridge. Five different rotations and two fertilizer treatments were selected on three replicates. Therefore, 10 individual plots per replicate were sampled. The 390 cm deep cores were separated into 30 cm increments. Soil moisture levels were measured and the samples sent to the Alberta Agriculture Soils and Animal Nutrition Laboratory where the soil analysis will be carried out.

All of the crops seeded were treated with the appropriate fungicide or inoculant, and when the developing plants reached the proper leaf stage, in-crop spraying was performed using suitable herbicides. The only plots that did not receive any herbicides were the "peas and oats" and "fall rye" plots in rotation 9. This rotation was selected as a "low input" rotation. All fallow treatments were cultivated approximately once a month to control weeds and conserve soil moisture.

During the fall of each year, cores are sampled from each plot to a depth of 0.6 meters. The samples are separated into three increments: 0 - 15 cm., 15 - 30 cm., and 30 - 60 cm. Plant available nutrient levels (N,P,K,S) are measured and recorded. Only three of the four replicates are sampled each fall, this is done to cut down in soil loss as well as labour and analysis costs. This year replicates 2, 3 and 4 were sampled. The results of the plant available nutrient analysis for the continuous wheat rotation are summarized in Table 1.

Table 1. Mean plant available nutrients.

Rot. Trt. #	Sample Depth (cm)	Nutrient Type	Manure (PPM)	N & P (PPM)	N (PPM)	P (PPM)	No Fert. (PPM)
1	0 -15	NO_3-N	6.3	4.0	3.7	3.3	3.3
1	15-30	NO_3-N	1.3	1.0	1.3	1.0	1.3
1	30-60	NO_3-N	1.7	1.7	1.0	1.5	2.0
1	0 -15	PO_4-P	7.3	12.3	4.7	9.0	5.7
1	15-30	PO_4-P	2.0	1.0	1.0	4.0	0.0
1	30-60	PO_4-P	2.5	0.0	0.0	0.0	0.0
1	0 -15	K	264.7	306.0	295.0	286.3	302.3
1	15-30	K	197.0	237.0	243.3	210.3	275.0
1	30-60	K	243.3	283.3	256.3	244.7	243.0
1	0 -15	SO_4-S	7.4	8.9	7.5	8.7	8.2
1	15-30	SO_4-S	8.5	8.8	9.6	8.8	9.6
1	30-60	SO_4-S	82.6	42.0	61.0	93.9	409.5

Each spring, prior to seeding, 1.2 meter deep soil moisture samples are cored from each plot and separated into five increments. The moisture contents were determined and analyzed as randomized complete blocks. There was no significant difference between treatments. The soil moisture percentages, on a dry soil basis, were converted to depths of moisture. Millimetres of moisture data is more informative than percent soil moisture data, as it correlates with the millimetres of total rainfall. This data should be useful in determining moisture uptake for each crop variety. The depth of moisture data was obtained by use of the following formula:

(Soil bulk density/Density of water) * (Percent moisture of sample/100) * (Depth of sample in mm) = Depth of water in millimetres.

This conversion was made for each depth, and the five depths were summed together for each plot. The continuous wheat plot in replicate 1 had moisture contents of 21.51%, 19.52%, 21.94%, 16.69% and 17.55% for the 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths respectively. This formula converted the five "percent moisture" measurements into one measurement of 300.01 mm of available moisture.

The 1993 yield data was collected and recorded as planned. Total weights, grain weights and straw weights were measured and recorded. This was the second year of this rotational study and, because each stage of every rotation is seeded annually, it was possible to compare yields between rotations. Of the nine rotations selected, seven of these nine include wheat in their rotation, therefore wheat yields were used as a comparison between

the seven rotations. One of these rotations is "fallow - wheat - wheat". This rotation was split into two separate rotations, one measuring the yield of wheat grown after fallow, and the other which measured the yield of wheat grown after wheat. There was a total of eight different wheat treatments within seven different rotations and the rotations are as follows:

1. Continuous wheat
2. Wheat-canola-barley-peas
3. Fallow-wheat
4. Green manure-wheat
5. Fallow-wheat-wheat
6. Fallow-wheat-wheat
7. Fallow-peas-wheat
8. Fall rye-wheat-peas & oats

Yields for the above 8 wheat treatments were analyzed as randomized complete blocks. The results are graphed in Figure 1. A different letter above each bar denotes a significant difference between treatments ("a" is significantly different than "b").

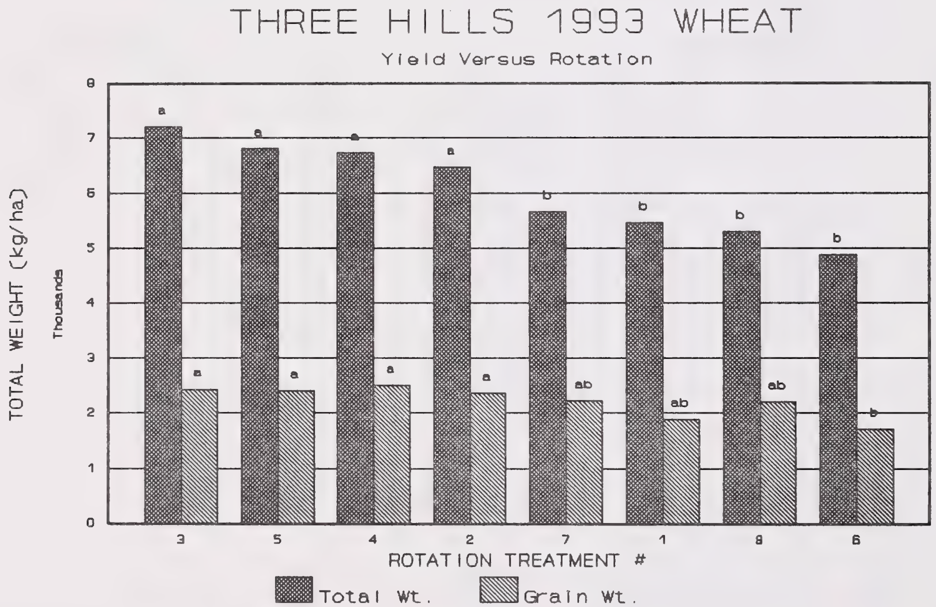

Figure 8 Values for each treatment labelled by the same letter are not significantly different at P=0.05.

The results in figure 1. for total weight show that rotation treatments 2, 3, 4, and 5 are significantly different than treatments 1, 6, 7, and 8. This is justifiable as wheat grown after fallow should have more moisture available for plant growth, and wheat grown after peas should have more nitrogen available, especially if the peas are green manured.

The grain yields, also shown in figure #1, were analyzed in the same manner as above, and treatments 2, 3, 4, and 5 were significantly different from treatment #6. Wheat grown after peas or a fallow year seemed to out-yield wheat grown after a cereal crop. Wheat

grown after peas (green manured) yielded the highest, and wheat grown after fall rye yielded the lowest. This lower yield could be due to an allelopathic effect from the fall rye.

The two remaining rotations did not involve wheat. These rotations were continuous forage crops. In the experimental plot plan these are Treatments #16 (continuous Brome grass) and #17 (continuous Alfalfa and Brome grass). Total dry matter, both early and late hay cuts combined, were analyzed as split plots. There was no significant difference between Brome alone and Brome plus Alfalfa; the means were 5857.3 and 5464.3 (kg/ha) respectively. There was however, a significant difference between fertilizer treatments for the forage plots. The nitrogen only and nitrogen plus phosphorous treatments yielded significantly higher than the phosphorous only and no fertilizer treatments. Manure yielded in the middle and was not significantly different from other treatments. The results are graphed in Figure 2 below.

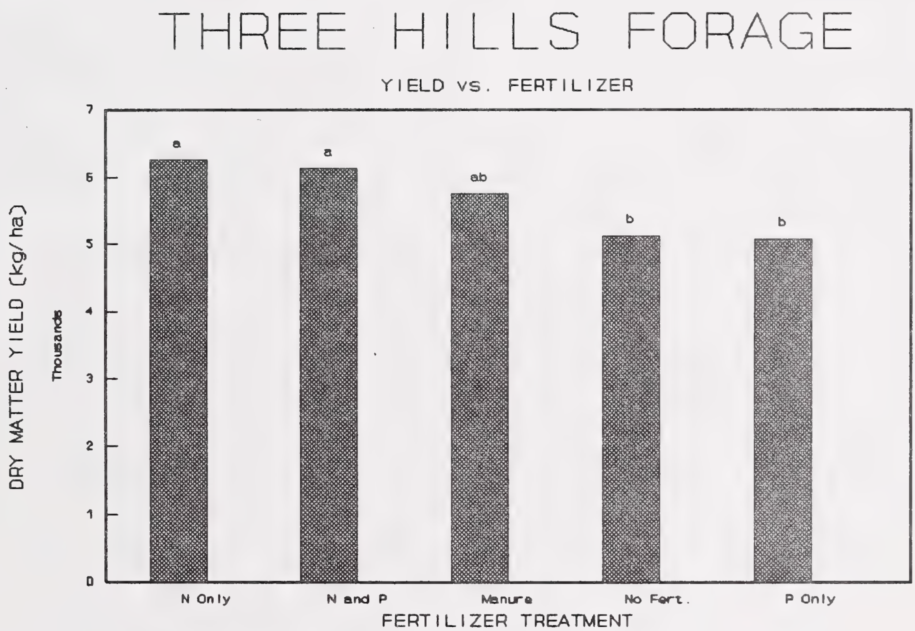

Figure 9 Values for each treatment labelled by the same letter are not significantly different at P=0.05

The weather station is fully operational and measurements are recorded every hour. Environment Canada has been very helpful in setting up the station and organizing the data. All 1993 weather data has been recorded and stored. Chart 1 lists some data of agronomic importance recorded during the growing season of 1993.

Chart 1

1993	May	June	July	Aug.	Sept.
Total Rainfall (mm)	38.6	96.8	77.2	32.5	24.9
Avg. Air Temp. (°C)	12.3	13.7	13.4	14.0	10.2
Avg. Wind Speed (Kph)	18.1	18.7	13.9	12.7	14.9
Max. Air Temp. (°C)	31.2	28.5	28.0	28.9	26.8
Avg. Max. Air Temp. (°C)	19.1	20.0	19.5	21.0	17.7
Min. Air Temp. (°C)	-2.6	1.2	3.5	2.5	-2.7
Avg. Min. Air Temp.(°C)	5.3	7.3	8.0	7.8	3.3
Avg. Soil Temp. (5 cm depth)	15.1	19.6	21.5	23.7	18.8
Avg. Soil Temp. (10 cm depth)	13.9	16.6	17.2	18.1	12.6
Avg. Soil Temp. (20 cm depth)	15.9	19.5	20.5	21.7	17.1
Avg. Soil Temp. (50 cm depth)	9.6	13.7	15.2	17.0	14.1

CONCLUSIONS

1993 was only the second year that these nine rotations were grown at Three Hills. Most of the rotations have not completed their first cycle, however comparison of the wheat yields between each rotation show differences at this stage already. Effects of crop rotation on the soil and crop yields will become more evident in future years. After several rotations, comparisons can be made from one year to another and results should be clearer and more informative.

All fertilizer treatments were analyzed as split plots. "Nitrogen only" yielded an average of 6604.2 kg/ha, which was significantly higher than the averages of the four remaining treatments. The yield averages for "nitrogen and phosphorous", "manure", "phosphorous only" and "no fertilizer" were 6049.2, 5786.5, 5596.9 and 5595.3 kg/ha respectively. One reason why "nitrogen only" yielded significantly higher than the other treatments could be that the soil has sufficient levels of phosphorous. When additional phosphorous with no additional nitrogen is added to the soil, the balance of nutrients available to the plants is disrupted, and this could have a negative impact on plant growth. The crops grown on manure-fertilized soil may require a few years to ensure proper mineralization and availability of nutrients for plant growth. The manure used in this study is a well-rotted manure which is purchased from the Olds college.

CLOVERS FOR FORAGE OR GREEN MANURE

Thomas L. Jensen[19]

INTRODUCTION

This report contains results from a research study looking at the crop yields when a clover crop is underseeded in a barley or canola crop, managed as forage the second year and a barley crop is grown on the field the third year. It was a joint project of Ducks Unlimited and Alberta Agriculture, Food, and Rural Development. Funding for the research was received from the Canada Alberta Research Technology Transfer Program (CARTT).

Nesting birds especially waterfowl need undisturbed plant cover on areas near wetlands to successfully nest. Farm field operations that cause disturbance from early spring until mid summer drastically reduce nesting success. An field management technique that helps the birds is when a hay field is left untouched during this period.

One technique that has been used is to underseed clover in a barley or canola crop and use the clover stand the following year for a delayed forage crop. The delayed forage means that the clover crop is not cut for hay or silage until after July 15th. This provides nesting cover for the birds, but the forage operations are a couple of weeks later than normal. One disadvantage to farmers is that the quality of the clover for livestock feed declines because the older clover plants have lower protein and higher fibre contents. Another is that the yield of the companion barley or canola crop the first year is somewhat reduced. The potential benefits to the farmer is that the clover can add plant fibre and fixed nitrogen to the soil, and the forage crop is a valuable source of feed for livestock.

The objective of this study was to assess the effects on crop yields of this technique.

METHODS

The study was conducted on a field six km southeast of Bashaw. The land had been purchased by the North American Waterfowl Management Plan because it was ideal for waterfowl nesting habitat. Ducks Unlimited had seeded the majority of the quarter section to dense nesting cover, grass and legume species. There are numerous permanent and temporary wetlands on the quarter and the upland fields planted to the grass-legume cover will provide birds with nesting area.

The research plots were located on a three acre field that was not seeded to dense nesting cover. The crop the year before was barley.

The underseeded clover for green manure or forage was a factorial experiment with three factors. The factors were the companion crop method, forage method and clover type.

The companion crop methods were as follows:
1. Barley with no herbicidal weed control, clover underseeded at the time of barley seeding.
2. Barley with Trifluralin herbicide used for weed control, clover underseeded at the time of barley seeding.

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3. Barley with underseeding of clover delayed until after two weeks following a post emergent application of Hoegrass II herbicide. Actual delay of underseeding of the clover was approximately one month.
4. Canola with no herbicidal weed control, clover underseeded at the time of canola seeding.
5. Canola with Trifluralin herbicide used for weed control, clover underseeded at the time of canola seeding.
6. Canola with Trifluralin herbicide used for weed control, delayed underseeding at the same time as number 3 above.

The forage methods were as follows:
1. Early forage cut, approximately 50 % bloom, near the third week in June, followed by a disking on July 15th.
2. Late forage cut, July 15th, followed by a disking.
3. Early disking as a green manure crop, at the same time as the early forage cut, followed by a disking after July 15th.
4. Late disking as a green manure crop, at the same time as the late forage cut.
5. Desiccate the clover using Banvel herbicide at the time of early forage cut, leave standing until July 15th and then disk.

The clover types were red clover and yellow sweet clover.
The companion crop method of underseeding was the main plots with forage method as split plots and clover type as split-split plots.

Measurements taken included the following:
- yield of companion crop (barley or canola),in year one
- dry matter yields of the clover at the early, and late forage cuts in year two
- the yield of the barley crop at harvest time, in year three.

RESULTS AND DISCUSSION

The underseeding of clovers in either barley or canola was done successfully. All of the clovers grew and became established in the first year.

The method of underseeding whether early or late, with or without a herbicide treatment, and the companion crop type did affect crop yields (Table 1). In barley delayed underseeding of the clovers following use of Hoe-Grass II herbicide to control weed growth resulted in a higher grain yield compared to barley with no herbicide, or barley with Trifluralin herbicide. The Trifluralin use in the barley did not produce significantly more grain compared to when barley was grown without a herbicide. Delaying the underseeding of the clover in the canola crop did not significantly increase the grain yield, as long as Trifluralin was used.

Table 1. The effect of underseeding method on companion crop yield, grain, Bashaw 1990.

Underseeding Method Crop - Herbicide - Time	Yield Tonne/Ha
1. barley-none-early	2.563 b*
2. barley-Trifluralin-early	2.073 bc
3. barley-Hoe-Grass II- delayed	3.254 a
4. canola-none-early	0.852 d
5. canola-Trifluralin-early	1.446 c
6. canola-Trifluralin-delayed	1.585 c
LSD 0.05 =	0.547

* different letters denote significant differences between treatments

Forage production in the second year of the experiment was affected by the various underseeding methods at both the early and late times (Table 2). All the early underseeding treatments resulted in higher forage yields compared to delayed underseeding at the early forage cut. At the late forage cut the delayed underseeding methods did improve relative to all the early underseeding treatments. The delayed seeding of clover in barley was the overall lowest yielding treatment.

Table 2. Forage yields by underseeding method at both the early and late forage cuts, Bashaw 1991.

Underseeded Method	Forage Yield Tonne/Ha	
Crop - Herbicide - Time	Early	Late
1. barley-none-early	5.0	6.1
2. barley-Trifluralin-early	5.8	6.7
3. barley-Hoe-Grass II-delayed	2.4	4.0
4. canola-none-early	3.9	5.1
5. canola-Trifluralin-early	5.2	6.0
6. canola-Trifluralin-delayed	2.8	4.8
LSD 0.05 =	0.9	1.0

* different letters denote significant differences between treatments

Late forage cutting resulted in higher yields than early forage cutting, the respective averages were 5.5, and 4.2 Tonne/ha (LSD=0.3 Tonne/ha). There was a slight increase in the fibre content of the forage, resulting in the forage being of somewhat lower quality. When comparing the two clovers, red clover was the least affected by this increase in fibre content. At the late forage cut the fibre contents were 26% for the red clover, and 30% for the sweet clover.

The red clover yielded significantly more than the sweet clover at both of the forage cuts (Table 3).

Table 3. Forage yields by clover species and time of forage cut

Species	Forage Yield Tonne/Ha Early Cut	Late Cut
Red Clover	4.4	5.8
Yellow Sweet Clover	3.8	5.0
LSD 0.05	0.4	0.7

The experimental factors of underseeding method, and forage method had minimal effects on the barley yield in the third year. This would indicate that farmers have many choices as far as underseeding method, forage method and clover type when considering the effect on future crops. Of 9 farmer cooperators who participated in clover underseeding as part of a related field demonstration, all of them choose to use the clover crop for forage, as hay or silage. If farmers have their own livestock to feed or could sell forage to neighbours, who have livestock, they will probably choose a forage cut over green manuring.

CONCLUSIONS

1. If clover underseeding is done in a companion crop, early underseeding at the same time as the companion crop is preferred over delayed underseeding. This is because of the greater forage production in the second year, for the early compared to the delayed underseeding.

2. Use of a suitable herbicide (compatible to both the companion crop as well as the underseeded clover, eg Trifluralin) when underseeding is advised. In both the barley and canola companion crops weed growth was decreased. As far as companion crop yields, the canola yield was enhanced and the barley yield was not reduced.

3. The choice of underseeding, and forage methods, appears to have little effect on the yield of a subsequent barley crop in the third year. This allows the farmer a lot of choice and flexibility as to what methods he wants use on his farm. There will be little long-term differences between the methods chosen as far as it affects future crop yields.

4. Both red clover and sweet clover can be used as underseeded clovers. Red clover can result in higher forage yields if rainfall is moderate to good. Under drier conditions the forage yield of the sweet clover may have been greater compared to the red clover. In most of the Parkland area of the Prairie regions of Western Canada, the

red clover will be more suitable for wildlife habitat enhancement if underseeded in a companion crop and used for forage in the second year.

5. Delaying the forage cut in the second year, allows nesting waterfowl adequate time to hatch their eggs, and move their young one to adjacent wet areas. This delay has two major effects on forage yields. First the delayed forage cut allows more forage to be produced per acre, but secondly the forage quality decreases slightly as the older clover growth is higher in fibre content. This is an area of research that needs further, more detailed investigation.

6. There is no advantage of green manuring compared to a forage cut of the clover crops in the second year when the yield of the subsequent barley crop is considered. In most cases a farmer would probably use the clover as a forage rather than green manuring, unless there is no livestock to feed the forage to on the farm or within a reasonable distance of the farm.

GROWTH OF CANOLA AND BARLEY CULTIVARS USING CONSERVATION TILLAGE

Thomas L. Jensen[20]

INTRODUCTION

The use of conservation tillage is increasing on the Canadian Prairies. In Alberta alone the use of conservation tillage has increased from 43% to 75% over the past 5 years (Haig and Haig 1992). This 75% is largely reduced and minimum tillage. However the specific use of no-tillage has tripled over this same period from 1% to 3%.

It is expected that the use of no-tillage or direct seeding will increase even more because of the economic advantage of using no-tillage compared to conventional tillage. By using no-tillage, farm managers can save costs in equipment, labour and fuel. In most cases crop yields are similar to conventional tillage.

Most studies to date comparing conventional tillage to conservation tillage (reduced, minimum and no-tillage) have used only one cultivar of a specific field crop. There is a lack of information as to whether certain cultivars grow differently, compared to other cultivars of the same species under the various tillage environments (conventional and conservation forms).

The objectives of the study in this report are the following:

1. To compare the yield of nine barley and five canola cultivars under conventional tillage (CT), minimum tillage (MT), and no-tillage (NT) or direct seeding.
2. To observe whether there is an interaction between tillage system and species cultivars, when yield measurements are compared.

METHODS

Nine barley and 5 canola cultivars were grown using 3 different tillage systems (CT, MT, and NT) for 2 years (1991 and 1992) at 2 separate sites for each species, or 4 field sites each year. The 2 barley sites were at Ellerslie, and Wainwright. The 2 canola sites were at Calmar and Strome.

In 1991 a randomized complete block design was used for the barley cultivars and a split block design for the canola cultivars. In 1992 the split block design was used for all the sites.

The tillage systems are explained as follows:

1. No-tillage was the same under all the experiments. Canola or barley was directly seeded into wheat stubble with no prior tillage. Roundup herbicide (1 L ha^{-1}) was applied one day prior to seeding.

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2. Minimum tillage for the barley experiments consisted of one cultivation (chisel plow operation at 254 mm spacing using 300 mm sweeps, with attached spring harrows) prior to seeding. For canola there was one cultivation as used for barley, an application of Edge herbicide (dispersible concentrate 0.77 kg ha^{-1}) immediately followed by a second cultivation and a third cultivation a few days later.
3. Conventional tillage for both barley and canola started with a cultivation in the fall of the previous year after harvesting the wheat crop. In the spring of the following year there was a double discer operation then two cultivations. The canola plots had an application of Edge herbicide after the discing but prior to the last two cultivations.

Analysis of the results was done using Analysis of Variance for the experimental design used at the specific site (either randomized complete block or split block).

RESULTS AND DISCUSSION

The effects of the three tillage systems on the yields of canola and barley cultivars will be discussed separately.

Canola Results

Of the four site years summarized in Table 1, only the Strome site in 1991 showed any cultivar x tillage interactions. There were some differences between cultivars and tillage systems observed in the other three site years.

Table 1. Summary of analysis of variance, two sites, and two years, for five canola cultivars and three tillage systems.

Source	Yield Measurement	Significance by Site and Year			
		Calmar		Strome	
		91	92	91	92
Cultivar (C)	Total wt.	ns	*	ns	ns
	grain wt.	ns	*	ns	ns
	straw wt	ns	*	ns	ns
	harvest index	**	*	ns	**
Tillage (T)	Total wt.	ns	***	ns	**
	grain wt.	ns	***	ns	**
	straw wt.	ns	**	ns	***
	harvest index	ns	ns	ns	***
C x T interaction	Total wt.	ns	ns	*	ns
	grain wt.	ns	ns	*	ns
	straw wt.	ns	ns	*	ns
	harvest index	ns	ns	ns	ns

ns= not sig., * sig. at P=.05, ** at P=.01, and *** at P=.001

At the Strome site in 1991 the Hyola 401 cultivar had higher total weight and grain yields using no-tillage and minimum tillage than conventional tillage. The cultivar Bounty conversely produced lower straw weights under minimum tillage and no-tillage than under conventional tillage. Lastly the cultivar Alto showed a higher harvest index for no-tillage and conventional tillage compared to minimum tillage (Table 2).

Table 2. Canola Cultivars Exhibiting Tillage x Cultivar Interactions, Strome Site 1991.

Cultivar	Tillage System	Yield Component	Yield Measured kg ha^{1}	LSD 0.05
Hyola	NT	Total wt.	6023 a*	1230
	MT		5936 a	
	CT		4531 b	
	NT	Grain wt.	1324 a	274
	MT		1303 a	
	CT		999 b	
Bounty	CT	Straw wt.	5571 a	1437
	MT		4034 b	
	NT		3800 b	
Alto	CT	Harvest index	.2166 a	.0284
	NT		.2099 a	
	MT		.1785 b	

* The same letters show non-significant differences

Barley Results

Of the four site years summarized in Table 3 below, the Wainwright site showed cultivar x tillage interactions in both 1991, and 1992. There were some differences between cultivars observed in all four site-years and between tillage systems in 1991 at the Wainwright site and in 1992 at the Ellerslie site.

Table 3. Summary of analysis of variance, two sites, and two years, for nine barley cultivars and three tillage systems.

Source	Yield Measurement	Significance by Site and Year			
		Ellerslie		Wainwright	
		91	92	91	92
Cultivar (C)	Total wt.	*	ns	***	***
	grain wt.	***	**	***	***
	straw wt.	***	**	***	***
	harvest index	***	ns	***	**
Tillage (T)	Total wt.	ns	*	ns	ns
	grain wt.	ns	**	*	ns
	straw wt.	ns	ns	*	ns
	harvest index	ns	ns	ns	ns
C x T interaction	Total wt.	ns	ns	ns	**
	grain wt.	ns	ns	ns	*
	straw wt.	ns	ns	ns	ns
	harvest index	ns	ns	**	ns

ns= not sig., * sig. at P=.05, ** at P=.01, and *** at P=.001

The cultivars Condor and Abee had higher yields under CT compared to NT, and MT for a number of yield components as shown below (Table 4). In contrast the cultivar Noble had higher yields for MT, and NT compared to CT.

CONCLUSIONS

The results from this work show that there are some observable interactions between canola and barley cultivar types and tillage systems. However these type of interactions were observed in only three of the eight site years. This could mean that under most conditions the growth of canola and barley cultivars will be similar in relation to cultivars of the same species, whether CT, MT or NT cropping systems are used.

This is useful information because it shows that new cultivar releases selected using CT will result in relative yield rankings that will be valid even if the cultivars are grown under MT or NT and not CT.

Table 4. Barley cultivars exhibiting tillage x cultivar interactions, Wainwright site years 1991 and 1992.

Cultivar/ Year	Tillage System	Yield Component	Yield Measured kg ha[1]	LSD .05
Condor/ 1991	CT	Harvest index	.3729 a*	.0342
	MT		.2979 b	
	NT		.2930 b	
1992	CT	Grain wt.	2708 a	629
	NT		1766 b	
	MT		1455 b	
Abee/ 1992	CT	Total wt.	5568 a	1370
	NT		4002 b	
	MT		3712 b	
	CT	Harvest index	.3880 a	.1532
	NT		.2084 b	
	MT		.1352 b	
	CT	Grain wt.	2192 a	936
	NT		928 b	
	MT		466 b	
Noble/ 1992	MT	Total wt.	4814 a	2198
	NT		4756 a	
	CT		2262 b	
	MT	Straw wt.	3847 a	1183
	NT		3526 a	
	CT		2037 b	

* The same letters show non-significant differences

Comparisons of this type between CT, MT and NT have been done in other areas. Cox and Shelton 1992 published results from North Dakota evaluating 14 winter wheat cultivars grown under both CT and NT. Their study showed some significant cultivar x tillage interactions for some quality parameters, however they concluded that for relative yields the cultivars performed similarly under NT compared to CT.

A total of 23 sorghum cultivars were compared under CT and NT in Tennessee. In most years there were few interactions between cultivar and tillage method (Graves and Bradley 1990).

Philbrook et al (1991) compared 12 soybean cultivars under CT, reduced tillage, and NT. They observed cultivar x site interactions for many growth characteristics. However the relative yield differences, did not change significantly among tillage treatments. It was concluded that selecting cultivars using yield performance data from CT evaluations could identify the best yielding cultivars for use in NT and reduced tillage.

It would seem that from the results of the experiments summarized in this study and from references in the literature as mentioned above, there is little need to begin extensive cultivar evaluations under NT or MT, if data is available from trials under CT.

However Hwu and Allan (1992) raised the point that most existing crops lack sufficient genetic diversity to respond to natural selection for most traits affected by using conservation tillage systems. Most existing cultivars were selected under CT husbandry. With populations of crops that have or will be intentionally developed to achieve a broader genetic base, evaluation under more than CT will be justified.

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NO-TILL SEEDING OF BARLEY INTO SOD

J. Prochnau[21] and T. Jensen[22]

INTRODUCTION

The costs involved in converting hay or pasture fields into cereal crop production are high and time demanding. Intense tillage operations such as: ploughing, heavy discing, several conventional type cultivations, and harrowing are needed. These tillage operations are costly and allow the fields to become susceptible to wind and water erosion.

No-tillage or direct seeding of barley into a previous forage stand without pre-seeding tillage is possible using a direct seeding disk seed drill (eg. John Deere 750 series). Direct seeding with this type of seed drill lowers the operating costs and virtually eliminates the risk of soil erosion on the cropped land. In Canada's Parkland region of the Prairie Provinces, many mixed farm operations use a pasture-cereal or hayland-cereal rotation in their farm plan. However, there is little available information on converting hayland into a cereal crop using direct seeding practices within the Prairie Provinces.

To help develop information on this topic a research project titled "No-Till Seeding of Barley into Sod" was initiated by the Conservation & Development Branch of Alberta Agriculture Food and Rural Development. Funding was provided through the Farming For the Future program of the Alberta Agricultural Research Division.

METHODS

The "No-Till Seeding of Barley into Sod" project is at three sites within central Alberta: near Innisfail, Onoway, and Viking. Innisfail and Onoway were previously a pasture while the Viking site was previously a hay field of alfalfa and bromegrass. The sites near Innisfail and Viking are on loam textured black soil. The Onoway site is on a clay loam textured grey soil. The barley seeded at Innisfail and Viking was Bonanza while Onoway was seeded into Manley as the co-operating farmer is a seed grower of two-row barley varieties. Each site has 4 tillage treatments replicated 4 times in a randomized complete block design. All seeding was done using a John Deere 752 drill. The 4 tillage systems evaluated were:

1) <u>CONTROL</u> direct seeding without tillage or a preplant herbicide application but included post emergent spraying for broadleaf weeds.
2) <u>HEAVY DISCING</u> followed by 2 passes with a cultivator, harrowing, seeding and post emergent spraying as above.
3) <u>NO-TILL</u> seeding, following an application of ROUNDUP (1 L/acre) one week

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before seeding and including post emergent spraying.

4) PLOUGHING followed by 2 disc operations, one pass with a cultivator and harrows, seeding and post emergent spraying.

An electric fence powered by a solar panel was set up around the plots at Onoway to ensure there was no grazing on the plots.

All three sites were prepared for seeding during the third week of May. This allowed the forage grasses to grow sufficiently to be controlled with ROUNDUP. Soil moisture conditions tended to be poor at the Onoway site.

The quality of the seed-bed was determined by measuring soil temperature at seed depth, bulk density measurements, and the emergence of crop plants (# of plants per 1 m of seedrow) at 2 weeks after seeding. Observations and photos of weed control were monitored throughout the season. Growth stage of the crop was recorded bi-weekly for 2 months after seeding. The observations included counts of nodes, leaves, tillers, flag leaf stage, and dry matter weight for 2, 1 metre length rows. At harvest the total dry matter yield of top growth, grain yield and straw yield were recorded. The border area around each replicate block was mowed as required.

New replicate blocks are to be seeded adjacent to existing sites to be monitored in 1994. The existing plots that were ploughed or disced were cultivated in the fall of 1993. The no-till plots will stay the same along with the control plot and they will receive an application of ROUNDUP one week before seeding. The disced and ploughed plots will also be seeded in 1994 after cultivation to measure barley growth during a second year after a forage stand.

RESULTS

This was the first year of the 2 year study and all the lab results are not processed yet. The barley growth on the control treatments, both fertilized and nonfertilized was so poor that no samples were taken. Competition from the existing forage stand completely choked out the barley crop. There was both a fertilized (50 kg/ha N) and non-fertilized sub treatment for each tillage type. The grain yield results show that no-till seeding is feasible but tends to yield lower than the disced or ploughed treatments. The yields of each site were evaluated using a statistical analysis software. At Viking there was a significant difference between the no-till treatment and disced or ploughed treatments for the fertilized yields. The following Figures show the average yield of the six treatments sampled at the three sites.

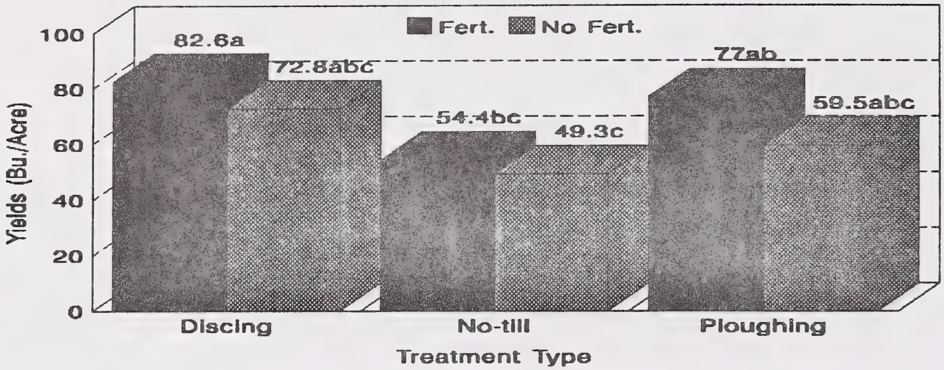

Fig. 1. Grain Yields at Innisfail - 1993

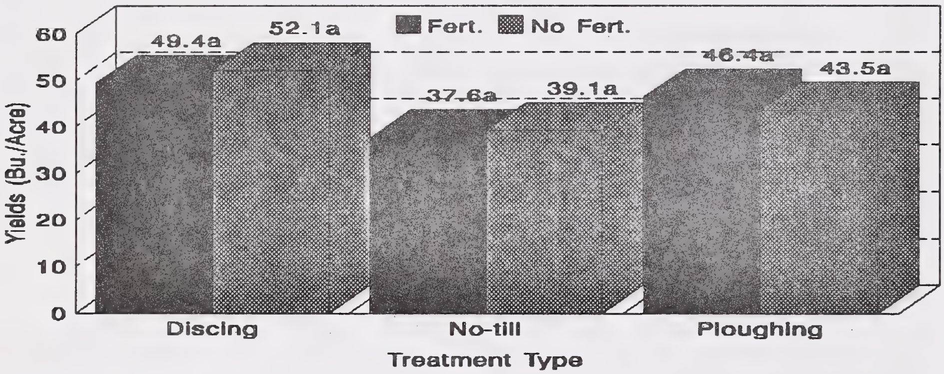

Fig. 2. Grain Yields at Onnoway - 1993

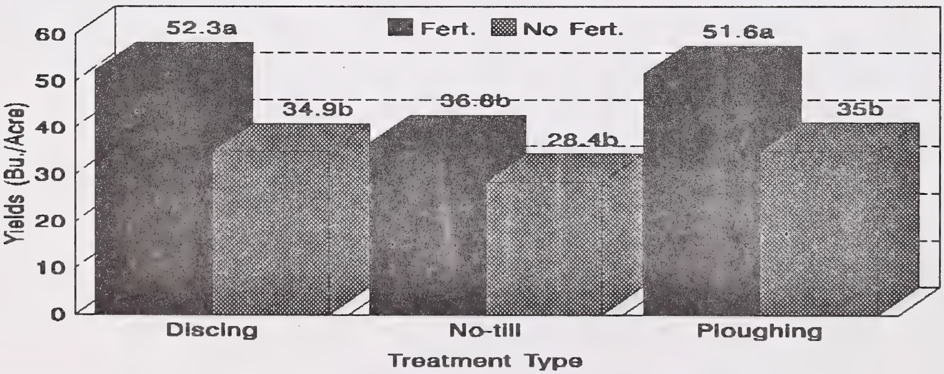

Fig. 3. Grain Yields at Viking - 1993

All the grain yields were calculated assuming 45 pounds of barley per bushel. The statistical analysis used in grain yields uses the Duncan's Multiple Range Test at a 95% confidence level. This same test will be used to analyze all the other data once the lab results are in. Analysis will be done on factors such as soil conditions at seeding, soil temperature, soil density, growth stages (ie. nodes, leaves, tillers, Feekes stage), and differences in nutrients (ie. N,P,and K) uptake by the crop.

Based on one year of sampling, the disced treatment performed the best at all three sites. A visual inspection showed that discing and ploughing had less grass and weed growth compared to the no-till seeding. Bromegrass and creeping red fescue were two grass types that provided strong competition to the barley in the no-till treatments.

Response from the co-operating farmers was very positive. The Innisfail site was part of a Zero Tillage Producer Tour on July 20, 1993. Tour members were very interested in the outcome of our demonstration and the visual differences of the tillage treatments.

A preliminary economic analysis of the different tillage treatments will be done this winter once all the lab results are completed. A complete analysis will be determined after 2 years of data are collected. These results will be valuable to farm managers interested in using direct seeding of cereal crops into forage stands.

CONCLUSIONS

No-till seeding, as part of a pasture-cereal or hayland-cereal rotation, can eliminate tillage operations. By incorporating no-till seeding, the fields are less susceptible to wind and water erosion. There are less input costs and less time involved in seeding. However, the results from the 1993 crop year indicate that no-till grain yields tend to be lower than conventional tillage yields. The results from this project will help to determine the economic feasibility. Further investigation of seeding barley into hay or pasture is needed.

The spread of yields between the fertilized and no-fertilized plots at Viking suggest that the amount of nitrogen fertilizer applied was not sufficient. In 1994, the plots will be conducted with 5 different rates (0, 30, 60, 90, and 120 kg/ha) of nitrogen to determine the yield response to nitrogen. This will help determine what rate of fertilizer should be applied if sod seeding is used.

Control of weeds and the forage grasses is very important. Spraying the grasses with ROUNDUP did control some regrowth of the forage grasses. There was still significant competition from the grasses in the no-till plots. The control plot reemphasizes the need to suppress the forage stand. It is virtually impossible for even a strong germinating crop such as barley to be able to survive. A second year of seeding barley into the existing 1993 no-till plots will allow measurement of the amount of regrowth from the forage grasses when barley is grown using no-tillage for a second year. A detailed count on the kinds and numbers of weeds and grasses present will be carried out.

The results from this Farming for the Future Project will help in the evaluation of this cropping technology. The great cooperation of the farm managers on whose farms we are conducting research is greatly appreciated.

ENHANCED WILDLIFE HABITAT THROUGH CONSERVATION FALLOWING

Thomas L. Jensen[23]

INTRODUCTION

Modern, mechanized agriculture can be detrimental to wildlife. Especially when crops are grown in large fields and the tillage practices used leave very little crop residue on the land. One practice that is especially hard on wildlife is when fields are fallowed for a year using tillage. The field becomes a desert wasteland for wildlife. There are few food sources, no places to hide from predators or find shelter from the elements.

Fortunately there are alternate fallow methods that can provide plant cover for wildlife and benefit the farm. One such method is a conservation fallow system where some or all tillage operations are replaced with herbicide applications. The important principle is that tillage not be used on the fields till after July 15th. After this date most nesting waterfowl and other birds have hatched and moved their young. Tillage operations on the fields earlier result in nesting failure. Farmers benefit by maintaining sufficient crop residue on the field to reduce wind or water erosion. The costs of the herbicide applications are offset by reductions in fuel and machinery costs compared to a conventional tilled fallow.

The study described in this report was a joint project of Alberta Agriculture, Food and Rural Development and Ducks Unlimited. Funds for the project were in part from the Canada Alberta Research and Technology Transfer (CARTT) Program.

METHODS

The study was located on prime waterfowl nesting land purchased through the North American Waterfowl Management Plan (NAWMP). The research plots were located on an upland field near to permanent wetlands. Because of the small size of the research plots, the measurements done were on the agronomic effects on crop yields and not on waterfowl nesting success. Wildlife biologists were making nesting success assessments on large farm fields during the same period. The conservation fallow experiment consisted of six experimental treatments as follows:

1. Herbicide (Roundup 0.75 l/acre, plus Banvel 200 ml/acre) as needed during the growing season, no tillage operations.
2. Herbicide as above until July 15th, then tillage operations as needed.
3. Herbicide, 2,4-D (230 ml/acre) as a separate operation early in the fallow season, followed by Roundup + Banvel as needed, no tillage operations.

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4. Herbicide fallow as in treatment number 3 above until July 15th, then tillage as required.
5. Conventional tilled fallow.
6. Continuous barley crop, including fertilizer (60 and 30 kg/ha respectively for Nitrogen and P_2O_5), and broadleaf herbicide control.

A randomized complete block design was used with four replicates. Individual plot or treatment size was 9 m by 15 m. Measurements taken included soil moisture contents, plant available soil nutrient levels, and barley crop yield the following growing season. The fallow treatments were done in 1990 and the subsequent barley crop was grown in 1991.

RESULTS AND DISCUSSION

The conservation fallow experiment treatments went ahead as planned. The first measurements from the plots were soil moisture samples taken in the fall of 1990. The 5 fallow methods used resulted in similar levels of soil moisture. The control treatment (barley crop) had lower average soil moisture levels than the fallow methods (Table 1). The methods where some or all of the tillage operations were replaced with herbicides conserved significantly more residue for wildlife. Important aspects to consider are what the effect of the various fallow methods have on the yield of the subsequent crop, and what is the overall economic cost and return to the farm operation.

Table 1. Average soil moisture levels (% dry soil basis, 1.2 m depth) for the 5 fallow, and the one control (barley crop) method, Bashaw 1990.

Fallow Method	Avg. Soil Moisture %
1. Roundup + Banvel, Herbicide only	18.3 a*
2. Roundup + Banvel, tillage after July 15	17.2 a
3. 2,4-D, then Roundup + Banvel, Herbicide only	18.7 a
4. 2,4-D, then Roundup + Banvel, tillage after July 15	17.9 a
5. Conventional tilled fallow	17.9 a
6. Control (barley crop)	13.8 b

LSD (Least Significant Difference) 0.05 = 3.1, * different letters indicate significant differences between treatments.

The effect of the various fallow methods on the subsequent barley crop are summarized in Table 2. The only observable difference between the fallow methods was that the early 2,4-D followed by Roundup + Banvel, herbicide only method, resulted in higher total crop growth (mass basis), and grain yield than the early 2,4-D followed by Roundup + Banvel, and tillage after July 15th. All of the fallow methods resulted in higher yields than the crop after barley.

Table 2. Crop yields as affected by fallow method, Bashaw 1991.

Fallow Method	Yield Parameters Tonne/Ha		
	Total Crop	Grain	Straw
1. Roundup + Banvel, Herbicide only	6.186 ab	3.168 ab	2.940 a
2. Roundup + Banvel, tillage after July 15	5.721 ab	3.017 ab	2.561 a
3. 2,4-D, then Roundup + Banvel, Herbicide only	6.687 a	3.763 a	3.019 a
4. 2,4-D, then Roundup + Banvel, tillage after July 15	4.549 b	2.282 b	2.267 a
5. Conventional tilled fallow	5.957 ab	3.161 ab	2.924 a
6. Control (barley crop)	1.981 c	1.103 c	0.879 b
LSD 0.05 =	1.419	0.981	0.636

* different letters indicate significant differences between treatments, each yield parameter analyzed separately.

To understanding the economic profit or loss of the different fallow methods, the input costs (materials plus labour and equipment) can be subtracted from the gross returns. Custom rate values can be used for the machine operations to estimate equipment and labour costs). Herbicide costs and grain prices are at current market values(Dec. 2, 1993). The input costs, gross returns, and net returns are summarized in Table 3.

Table 3. Input costs, gross return, and net return for the 5 fallow methods, Bashaw 1991. (per acre basis, over 2 years)

Fallow Method	Input Costs $	Gross Return $	Net Return $
1. Roundup + Banvel, Herbicide only -three applications	48.09	121.78	73.69
2. Roundup + Banvel, tillage after July 15 -two herbicide applications, two cultivations	42.06	121.52	79.46
3. 2,4-D, then Roundup + Banvel, Herbicide only -three applications, one 2,4-D, two Roundup + Banvel	36.06	144.68	108.62
4. 2,4-D, then Roundup + Banvel, tillage after July 15 -two herbicide applications, then two cultivations	30.03	87.73	57.70
5. Conventional tilled fallow -six cultivations	30.00	115.99	85.99

Prices $/acre of inputs: Roundup 0.75 L rate = $7.13, Banvel 200ml rate = $5.90, 2,4-D 230 ml rate = $1.00, spray operation = $3.00 and cultivation = $5.00.
Barley value = $95.00/Tonne.

Using the yield results from this experiment the highest net return was from treatment 3, at $108.62/acre. The input costs were somewhat higher than the conventional tilled fallow treatment, but the yield observed was greater. Land owners can use the conservation fallowing techniques (treatments 1, 2, and 3) as viable alternatives to a conventional tilled fallow. Crop residue can be maintained on the soil surface to enhance wildlife habitat while causing no economic disadvantage to the farmer.

CONCLUSIONS

The use of herbicides to replace tillage operations in the spring, and early summer of a fallow year were shown to be advantageous when measuring the effect on the yield of the subsequent crop, and farm economics. In this study the highest returns per acre were in fact a fallow method where all of the usual tillage operations were replaced with herbicides. Use of this type of conservation fallow technique will help supply wildlife with enhanced habitat.

CONSERVATION - WATER MANAGEMENT

EFFECT OF STUBBLE HEIGHT ON MOISTURE CONSERVATION, SOIL TEMPERATURE & YIELD

FFF Project No. 930318

A. Howard[24], J. Michielsen, G. Verity[25], and G. Peers[26]

INTRODUCTION

As a result of the persistent drought during the 1980's, there has been considerable interest in ways to conserve dryland soil moisture in the MD of Acadia. The MD is located in the Brown Soil Zone, which has the most severe moisture deficit in the province, however, much of the area has soils derived from lacustrine material. Because of the high clay content in these soils, they are capable of holding a good moisture reserve. In crop-fallow rotations in this area, even when subsoil moisture is sufficient, seedbeds are often dry and can result in delayed growth and uneven germination. Using stubble to trap snow has resulted in increased seedbed soil moisture elsewhere on the prairies (Tessier et al., 1990; Nicholaichuk and Gray, 1986) however, questions have been raised as to whether it is feasible for the crop management practices used on heavy clay soils in the MD of Acadia. Maintaining taller stubble during the fallow year has the potential drawback of reducing weed control options, raising the potential for increased runoff during spring melt, and delaying soil warming.

The objective of this project is to compare three practical ways of using stubble to trap snow by monitoring their impact on spring soil moisture and temperature, crop performance and economic feasibility. The study began in 1993 and is expected to continue until 1999. This report presents the results of the first year of the study.

METHODS

A site was selected at NE 16-24-2-W4, six miles south of Acadia Valley (Figure 1). Preliminary sampling was completed in May 1993, immediately after seeding. The field was level and in a spring wheat/fallow rotation with a strip cropping pattern. The soils were classified as Orthic Brown Chernozems developed in lacustrine material, based on visual examination of the soil profile and comparison to the criteria identified in the Canadian System of Soil Classification (Agriculture Canada, 1987). Two strips, one seeded to spring wheat and the other in fallow during 1993 were chosen for the study. Clay content within the strips ranged from 51% to 64% at the surface, and increased below 60 cm depth. The one exception was a small area on the north side of the fallow strip site where the texture

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ranged from Clay Loam to Sandy Clay Loam throughout the 150 cm profile. This area was excluded from the study, as were two areas which showed evidence of ponding. No accumulations of salinity or sodicity were evident on the site.

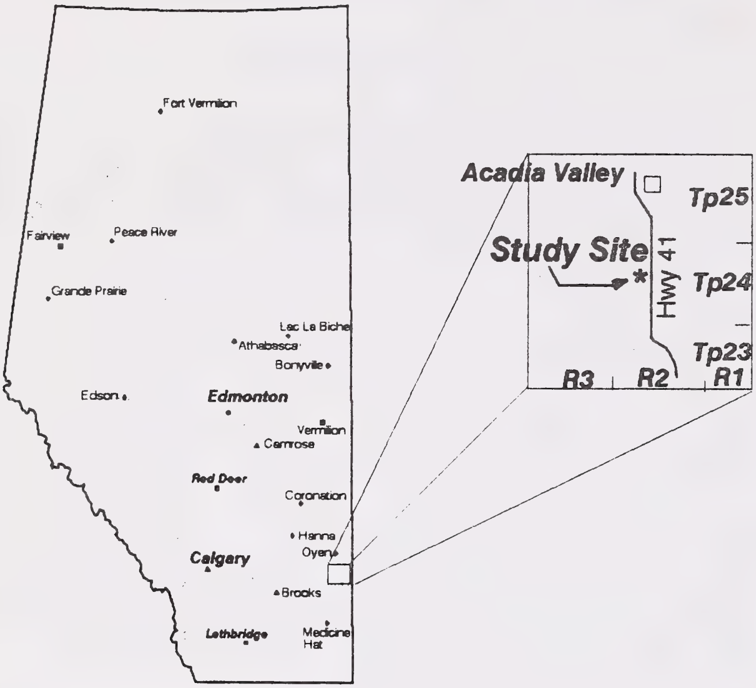

Figure 1. Location of study area

The three stubble conditions include stubble from swathing (short stubble), stubble from direct combining (tall stubble), and trap strips of tall and short stubble (alternate height stubble). The project design, illustrated in Figure 2, provided for 12 plots (4 reps x 3 treatments) in the stubble strip and 12 additional plots in a nearby chemfallow strip. By utilizing two sets of plots, data pertaining to moisture, temperature, crop growth and yield can be obtained on a yearly basis. The chemfallow strip was last harvested in 1992, and there-fore has no stubble treatments for this year. Four plots were instrumented for background information in the chemfallow and the remaining eight plots will be instrumented when the stubble treatments are applied in the fall of 1994.

Due to the late crop maturity this year, site installation did not commence until October 12. All plots were combined in a single operation, leaving tall stubble (70 cm height) on the entire strip. The short (conventional) and the alternate height plots were cut later, the short stubble to 25 cm height. The alternate height plots were made by cutting 40 cm high strips into the tall stubble. Fall soil moisture was determined by sampling at depths of 0-10, 10-20, 20-30, 30-40, 40-60, 60-80, and 80-100 cm depths and performing

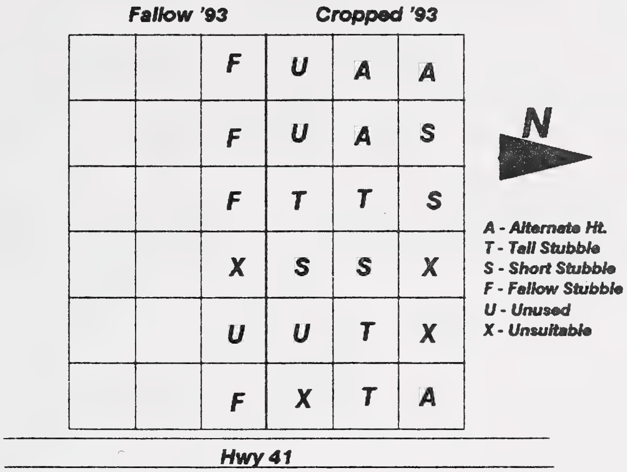

Figure 2. Plot layout for 1993-94.

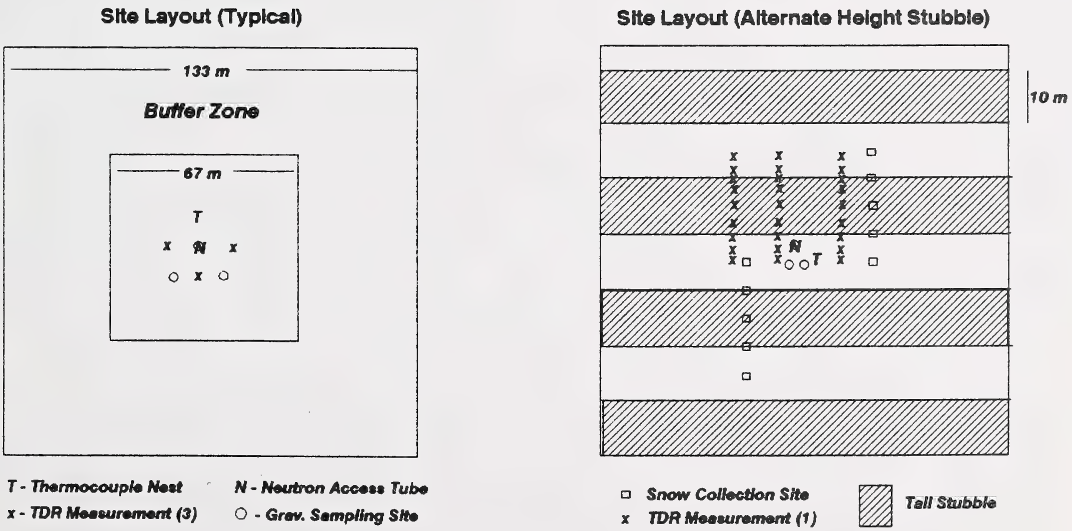

Figure 3. Sampling and instrumentation layout (not to scale).

gravimetric analysis. A neutron probe access tube was installed in each plot and thermocouples were installed at depths of 2, 5, 10, 50 and 100 cm. Surface soil moisture data was also obtained using Time Domain Reflectometry (TDR) at several locations within each plot. The measurements were made in clusters of three near the gravimetric sampling area in all plots except the alternate height stubble (Figure 3). In these plots, the measurements were made across the tall strip at three locations.

Soil temperature is monitored continuously from November through to seeding with a CR-10 datalogger installed at one replicate of each treatment. In March, a relative humidity sensor will be activated for each datalogger, and soil temperature at the plots without dataloggers will be measured manually.

A nipher snow gauge was set up to measure overwinter snowfall, and snow accumulation on the plots will be monitored until snowmelt by measuring both depth and water content of the snow. Snow samples are taken with a Montrose Prairie Snow Sampler at predesignated points along two transects across each plot (Figure 3). Water content is to be determined by bagging and weighing the snow samples.

Rainfall will be continuously recorded with a tipping bucket raingauge during the frost-free period, and soil nutrient levels will be determined by sampling prior to seeding. Costs and economic returns will be recorded and used in determining the economic benefit of each treatment.

RESULTS

A summary of the fall soil moisture data is presented in Table 1. Soil moisture conditions were wetter than usual as a result of the wet conditions experienced during the summer and fall. Based on 12 years of soil moisture surveys and estimates of total moisture content, levels in this area typically range from 250 to 300 mm in the stubble fields. The fallow plots averaged at least 75 mm more moisture than the stubble plots.

Table 1. Data summary for total soil moisture in the top metre at the Acadia Valley plots, October 1993.

	TALL	SHORT	ALTERNATE HEIGHT	FALLOW
MEAN SOIL MOISTURE (mm/m)	370	348	370	446
STD. DEVIATION	24.4	29.6	35.8	22.2
MINIMUM/MAXIMUM (mm/m)	328/392	299/384	323/432	415/483

Snow precipitation and accumulation data taken to February 1994 is presented in Table 2. Precipitation from November through January was 99% of normal based on the 30-year average from Medicine Hat. A permanent snowcover began in early November, and by early February the snow had completely filled the short stubble plots. The short stubble plots had the shallowest depth of snow cover and lowest water equivalent. The alternate height treatment had similar average snow depths to the tall stubble but it had the highest average water equivalent. The tall stubble had the lowest snow density, which reduced the water equivalent of the snow cover.

Table 2. Snow precipitation and accumulation averages for the tall stubble, short stubble and alternate height stubble at Acadia Valley, February 1994.

	TALL	SHORT	ALTERNATE HEIGHT[1]
WATER EQUIVALENT (mm)	53.37	30.94	62.46
SNOW DEPTH (cm)	29.77	14.76	29.43
DENSITY[2] (gm/cm^3)	.179	.210	.212
PRECIPITATION (Nov/93-Jan/94)	52.8 mm		

[1] Represents average of short and tall strips.
[2] 1 g/cm^3 = 10 mm water/cm snow

The snow densities are consistent with central Montana data for a relatively "fresh" snowpack (Caprio et al, 1986), and as the snowpack ages, the densities can be expected to increase toward 0.35 g/cm^3 by late winter. The central Montana data also showed that the average snow density in tall stubble fields tended to be lower than that of short stubble fields in areas subjected to a high frequency of chinooks. During Montana winters the tall stubble consistently retained deeper snowcovers and higher water equivalents than the short stubble.

Snow depth and water equivalent profiles in the alternate height stubble (Table 3) show the deepest accumulations and highest water equivalents were found in the centre of the tall strip. The centre of the tall strip contained 11 cm more snow and had a water equivalent 30 mm higher than the tall stubble plots, despite having the same stubble height. The west edge (the windward side) consistently had higher densities and water equivalents than the east edge (leeward side). The depth and density profiles indicate that the influence of the strips on the wind is likely a significant factor in the snow depth and density distribution across the strips. More sampling data and information on the dynamics of wind behaviour and trap strips is needed before these trends can be confirmed.

Table 3. Average snow accumulation across a tall stubble strip along a transect from the midpoint of the adjacent short stubble strip on the west to the midpoint of the adjacent short stubble strip on the east.

	MIDDLE SHORT WEST	WEST EDGE	MIDDLE TALL	EAST EDGE	MIDDLE SHORT EAST
WATER EQUIVALENT (mm)	48.8	75.4	83.5	64.5	49.3
SNOW DEPTH (cm)	22.3	34.5	41.4	31.8	22.4
DENSITY (gm/cm^3)	.219	.219	.202	.203	.220

CONCLUSIONS

The background information acquired for the study enabled the plots to be established on relatively uniform heavy clay soils, and reduce some of the variability associated with field scale plot work. A more detailed examination of the variability will be possible when all soil texture analysis has been completed.

Data that will relate stubble height to seedbed soil moisture, soil temperature, crop performance, and economic feasibility will not be available until 1995, which is the first time the field will be seeded under the stubble treatments. The high levels of soil moisture encountered during the fall will reduce the chances of observing large recharge responses to the snowmelt during the spring of 1994.

The preliminary snow accumulation data show that alternate height stubble has a higher potential for holding snow and water than tall stubble. Despite having similar average snow depths, the alternate height stubble held about 20% more water in the snowpack than did the tall stubble. The higher snow densities in the alternate height stubble, especially in the short strips and along the windward side of the tall strips, resulted in the higher water equivalents. This appears to be a result of the packing action by the wind. Both the tall and the alternate height stubble were holding about double the water equivalent of the short stubble.

Because this is an early stage of the project, further investigation is required to more firmly establish a relationship between the snow densities, the trap strips, and the wind.

ACKNOWLEDGEMENT

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A METHOD FOR MODELLING ALBERTA SOIL MOISTURE CONDITIONS

A. Howard[27] and J. Kirtz[28]

INTRODUCTION

Soil moisture maps for dryland stubble fields have been produced annually since 1982 for the fall and since 1988 for spring. The maps are based on determination of soil moisture from samples taken across the province during October and April. The maps have served as an important tool for the prediction of crop performance and determining the potential for drought in the province, however, there is a need to reduce the costs associated with production of the maps.

Components of a model used by the Winnipeg Climate Centre (Raddatz, 1989) were acquired by the Conservation and Development Branch in 1991 in order to assess their suitability for providing near real-time soil moisture estimates during the growing season. The WCC model was based on the approach of Dunlop and Shaykewich (1982) who applied concepts similar to those in the Versatile Soil Moisture Budget (Baier et al 1979). The approach used daily temperature and precipitation data from a given site along with non-daily (input once per year) soils, crop and location information from the site to calculate several agrometeorological products. WCC used the output, which included soil moisture, actual evapotranspiration (AET), and stage of crop growth on a prairie-wide scale as part of their weekly public bulletins.

The Winnipeg Climate Centre model was written in FORTRAN and operated on a mainframe computer. During 1992, the program was converted to a PC compatible version and tested during May and June of that year. Results showed that while the model could produce a coarse but useable description of soil moisture conditions on a provincial scale, the process of inputting climate data was cumbersome and time-consuming. Streamlining this feature required major revisions to the model.

During 1993, the revisions were initiated, essentially creating a new model that maintained the mathematical functions of the original. The goals of the project are to:

1. improve the resolution of the model for Alberta conditions
2. address minor discrepancies between predicted and observed soil moisture.
3. simplify the formatting requirements for inputting and managing daily climatic data
4. maintain enough flexibility in the model in order to address both research and production needs.

METHODS

The need to improve resolution arose from observing a general over-estimation of soil

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moisture levels in east-central Alberta when comparing model-generated maps and the sample-generated soil moisture maps. The model required non-daily inputs of water holding capacity (WHC) and initial soil moisture content (ISM) at each site. These, along with crop and location input data, were used with daily climate data to calculate daily soil moisture content at each site. The original model used 41 real-time climate recording stations as the Alberta sites. The result was a calculation of soil moisture data at each synoptic station, a total of 41 points in Alberta. Maps could be generated by drawing soil moisture contours, however there was no way to account for the influence of soil variability on soil moisture between points. The new program attempts to improve resolution by utilizing soil survey, crop statistics and soil moisture map information. With inputs from these sources, soil moisture calculations can be performed for every township in the agricultural zone of Alberta.

Water supply capacity information from Tajek et al (1989) replaced the WHC input and the data extracted from the spring soil moisture map replaced the ISM input. Crop information which included the dominant crop type, grain or forage, in every township provided the option to adjust soil moisture information for the local crop type or calculate provincial conditions for one crop type. The current soil moisture mapping procedure calculates provincial soil moisture for one crop type (small grains).

The climate data could not be obtained on a more detailed basis at the present time. Although there are over 300 climate recording stations in Alberta, only about 60 stations report data on a real-time basis during the growing season. It takes several weeks to obtain the data from the other stations. To utilize the real-time data, townships were assigned to the nearest climate station and climate data from that station was input into the township soil moisture calculation. Climate data consisted of actual and normal daily precipitation, maximum and minimum temperature.

The model was written in SAS. That system was chosen because climate and soil WHC information was readily available in SAS, which simplified formatting and inputting procedures, especially for the daily information. SAS can also handle large datasets quickly, reducing computing time. The ability of SAS to provide strong data analysis capabilities, a "push-button" operating system, and generate good graphic output was also considered essential features.

The model is initiated by calculating a complete set of data for every township using climate normals. When actual climate data is input, a second data set is generated, with the actual data replacing the normal data. New soil moisture values are calculated for the updated dataset. When a map of soil moisture conditions is requested for a given date, the map can be generated directly from the dataset. This method provides the opportunity to track moisture changes during the growing season, and also gives the option of using climate normals to predict conditions later in the growing season.

The model was developed in components in order to maximize flexibility. All mathematical formulas and parameters can be readily accessed and changed if necessary. Input climate data can be stored in multiple sets. The main dataset will utilize the Agricultural Weather Summary data from Alberta Agriculture, however, sets containing data from other sources can be easily created. Crop type can be set to grain, forage or combinations of both. As with the original version of the model, the stage of crop growth

and calculations of AET can be tracked along with soil moisture and compared to normals.

When the programming is completed the model output for October 31 will be compared to the corresponding fall soil moisture map for the years 1988-93. Percent of townships that are correctly predicted by the model will be assessed.

RESULTS

All programming activities have not been completed at the time this report was prepared, and therefore the models ability to simulate soil moisture conditions can not be evaluated as yet. Preliminary tests show satisfactory graphic reproduction of ISM and WHC, however, refinements to the handling of the climate input data are required before soil moisture or other output products can be evaluated.

CONCLUSIONS

The model is expected to reduce and likely eliminate the need for extensive sampling to present fall soil moisture conditions. In addition, the model will provide a means to quantitatively assess provincial soil moisture conditions during the growing season and predict the distribution of soil moisture conditions at later stages of the growing season.

The flexibility of the model will allow adjustments to be made to improve sensitivity by adjusting mathematical relationships if necessary. The ability to handle large datasets at different scales is expected to provide a versatile system that can be used in other applications of climate and soil information.

ACKNOWLEDGEMENT

The authors would like to thank Rick Raddatz of the Winnipeg Climate Centre for providing the model upon which the project was developed, and to Joe Tajek of Agriculture Canada, Alberta Soil Survey for providing the water supply capacity information used in the project. Special thanks is extended to Peter Dzikowski, Agricultural Weather Resource Specialist, Alberta Agriculture, for his input and review.

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LONG-TERM SOIL MOISTURE TRENDS IN ALBERTA

A. Howard[1], J. Michielsen[29], J. Bell[30], and R.T. Heywood[31]

INTRODUCTION

Soil moisture maps have been developed annually by Alberta Agriculture for stubble fields in the fall since 1982 and for spring since 1988. During the drought conditions of the late 1980's and early 1990's, several questions were raised by agencies using the maps about "normal" soil moisture levels. With the type of database available, (ie: maps with polygon units of soil moisture) a Graphics Information System (G.I.S.) appeared to provide the most reasonable approach to assessing longterm trends in soil moisture and identifying areas that are "usually wet" and areas that are "usually dry". In 1991, the Conservation & Development Branch undertook a G.I.S. analysis of the soil moisture maps to identify frequencies of various soil moisture levels in the fall and in the spring. The analysis required developmental work in implementation of software and writing of subroutines to link software and convert data. This report presents the final results of analysis of fall maps from 1982-1993 and spring maps from 1988-1993.

METHODOLOGY

The software used for the analysis was GEOSQL for the graphics analysis and R-Base for database storage and analysis. The analysis required that the map polygons be converted to a raster format for storage in the database, and the unit chosen was a township. The map polygons were overlaid on a township grid and each township was assigned a soil moisture level for every map. In the cases where a township contained a boundary between two soil moisture levels, the soil moisture level assigned was that level which was most representative of the township. The result was that the database contained a soil moisture level (Very Low, Low, Medium, or High) for each township within the Agricultural Zone of Alberta for every fall from 1982-1993 (12 years) and every spring from 1988-1993 (6 years). Frequencies were then calculated and the results stored as fields in the database. Queries were then made to the database to identify the frequency of chosen soil moisture conditions during spring and fall. Two conditions were identified, extremely dry and dry. Extremely dry conditions were defined as soil moisture levels in the Very Low category (less than 25mm of available water). Dry conditions were defined as soil moisture levels in the Very Low or Low

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category (less than 75mm of available water). Soil moisture levels below 75mm are considered insufficient to sustain crop growth past the seedling stage without timely and adequate precipitation. Soil moisture levels below 25mm are considered inadequate for successful germination without immediate precipitation.

The frequencies chosen were 0-3 years, 4-6 years, 7-9 years, and 10 or more years out of 12 years for the fall analysis. The spring analysis had frequencies of 0 years, 1-2 years, 3-4 years, and 5-6 out of 6 years. The responses to the queries were presented as maps. Percentages of each frequency were calculated by counting townships. The two maps representing dry years are presented in this report. Maps for extremely dry conditions (Very Low moisture levels) are available upon request.

RESULTS

<u>Fall Conditions</u>

The map titled *Frequency of Dry Falls* showed that since 1982, 14% of the province was dry at least 80% of the time, and 53% was dry at least 50% of the time, whereas 14% was dry less than 25% of the time, and 47% was dry less than 50% of the time. For the purposes of describing the map areas, the areas that were dry at least 80% of the time (red areas only) will be referred to as frequently dry. The areas that were dry at least 50% of the time (yellow and red zones) will be referred to as generally dry. The areas that were dry less than 50% of the time (green and blue areas) will be referred to as moderate.

Most of southeastern Alberta and parts of east central Alberta were frequently dry. This zone extends from the Montana border south of Foremost, northwest to Vulcan, north to Strathmore then northeast to the Neutral Hills, near Provost. A small zone extending from Wainwright northwest to Vermilion was also present.

Although the frequently dry zone is most prominent in southeastern Alberta, it does not follow a pattern that corresponds directly to either the Brown or the Dark Brown Soil Zones. The frequently dry area was larger than the Brown Soil Zone, and extends several townships west of the Brown Soil Zone near Calgary and Drumheller. It also extends several townships north of the Brown Zone near Lloydminster. A small pocket of frequently dry soils extends into the Black Soil Zone west of Lloydminster. The frequently dry zone extends as much as 75km west of the Brown soil zone near Calgary.

Almost all of southern Alberta, the eastern half of the province, and most of the Peace River region were generally dry. In northeastern Alberta, the generally dry area lies in a corridor roughly described by the longitude lines of 111^0 and 113^0. In the Peace River region, the central and southern portions of the region, with the exception of the Slave Lake-Valleyview area, were generally dry, as was the High Level area.

The generally dry area extends slightly west of the Dark Brown soil zone in southern Alberta, but it has extended far into the Dark Grey and Grey Wooded soils in northeastern Alberta and in the Peace River Region.

Only the Whitecourt-Swan Hills area, west-central Alberta, and parts of the northern Peace River region have had a low frequency of dry falls. Dry falls occurred least frequently in an area extending from the Swan Hills through Edson and Rocky Mountain House, then east to Red Deer. Although not shown on the maps, all areas of Alberta have

been dry at least once since 1990.

Spring Conditions

The map titled *Frequency of Dry Springs* showed that 10% of the province had dry seeding conditions at least 80% of the time, and 31% had dry conditions at least 50% of the time. For the remaining areas of the province, 44% had dry conditions at least once since 1988 and 15% had no years with dry seeding conditions.

There were three areas where insufficient soil moisture reserves for cropping occurred at least 80% of the time. The largest area extends south from Strathmore to Lethbridge, east along the Oldman River to Bow Island, northeast to Empress, then northwest to Coronation. The other areas were in northeastern Alberta, one was south of Lac La Biche, and the other was a strip that extends from Vilna southeast to Marwayne. The southern Peace River region, a large portion of northeastern Alberta, and most of east central and southeastern Alberta had insufficient reserves at least 3 out of 6 years.

The lower frequency of dry spring soil conditions in southwestern Alberta correspond to the presence of the foothills and the Milk River Ridge, and it is likely that these topographic features contributed to higher overwinter precipitation in this area. Lower frequencies of dry spring soils in the extreme southeast, in the Wardlow-Cessford area, and along the Saskatchewan border correspond to individual spring snowstorms during 1990 and 1991, which resulted in adequate soil moisture reserves in these areas. Because of the short data record, these storms resulted in a change in the frequency pattern of the map. Over a longer period, the effect of individual storms will have less impact.

The map of the frequencies of extremely dry springs (Very Low category) is not shown. Soils in this moisture category have insufficient moisture for successful germination and no reserve for seedlings and precipitation is needed immediately for successful crop growth. However 74% of Alberta has not been subjected to these conditions since 1988, and only three areas, totalling 4% of the province, were extremely dry more than 50% of the time. The largest area extends north from Medicine Hat through the M.D. of Acadia and Special Area 3 into the southern part of Special Area 4. The other two areas were west of Cessford and along the Bow River from the Vauxhall to Bassano. These areas were three and twelve townships in size, respectively. No part of Alberta experienced extremely dry seeding conditions more than 80% of the time.

CONCLUSIONS

All of Alberta, with the exception of the west-central area and portions of the northern Peace River region has experienced dry fall moisture conditions at least 50% of the time since 1982. Under these conditions, farmers must rely on adequate snowcover, favourable snowmelt and infiltration conditions, or heavy precipitation following ground thaw to replenish reserves. The fact that all of these areas experienced problems related to drought at least once during the 12-year period underlines the risk associated with dry fall soil conditions.

Eastern Alberta and the southern Peace River region were generally at risk of drought problems due to insufficient spring moisture reserves. In south central Alberta and portions

of northeastern Alberta, insufficient reserves have persisted since 1988, and chronic drought problems have been identified in these locations.

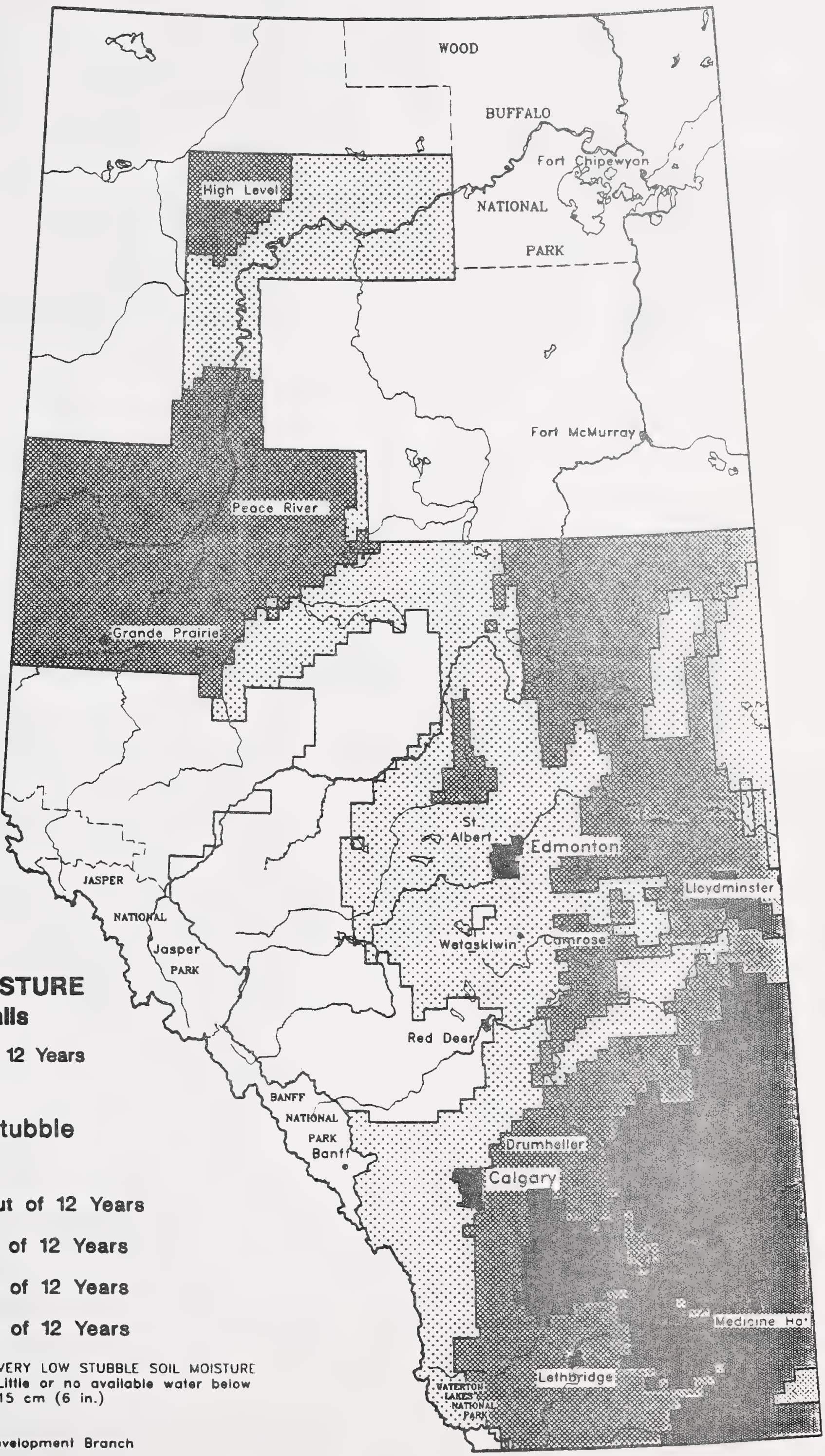
The frequently dry and generally dry areas were larger than the Brown and Dark Brown soil zones respectively. Although the frequently dry area generally extended into the Dark Brown, the generally dry area extended far into the Grey Wooded zone, where moisture deficits are lowest. The drier than average conditions that persisted throughout the 1980's were likely a major factor in the differences between the map areas and the soil zones. Other information needs to be obtained however, to establish whether these changes are transient, or reflect a longterm drying trend.

Normal overwinter precipitation is expected to produce improvements from inadequate to adequate soil moisture reserves for annual cropping in the northern Peace River region, the Red Deer-Camrose-Halkirk-Drumheller area, the Bonnyville-Cold Lake area, and the southwestern portion of Alberta. Because of the short record, the occurrence of individual spring snowstorms played a significant role in the overwinter gains. With a longer record, the effect of these storms may have less influence.

Use of snow management and other practices which conserve soil moisture will be essential to the success of crop and livestock production in the generally dry and frequently dry areas. Risk management practices aimed at understanding local and regional precipitation patterns will also be important tools for helping the agriculture industry deal with chronic moisture deficits.

ACKNOWLEDGEMENT

Appreciation is extended to Peter Dzikowski, Agricultural Weather Resource Specialist, C & D Branch of Alberta Agriculture, Edmonton for his ideas and input into the design of this project.



Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

STUBBLE SOIL MOISTURE
Frequency of Dry Falls

Analysis of Information From 12 Years of Fall Data (1982 - 1993)

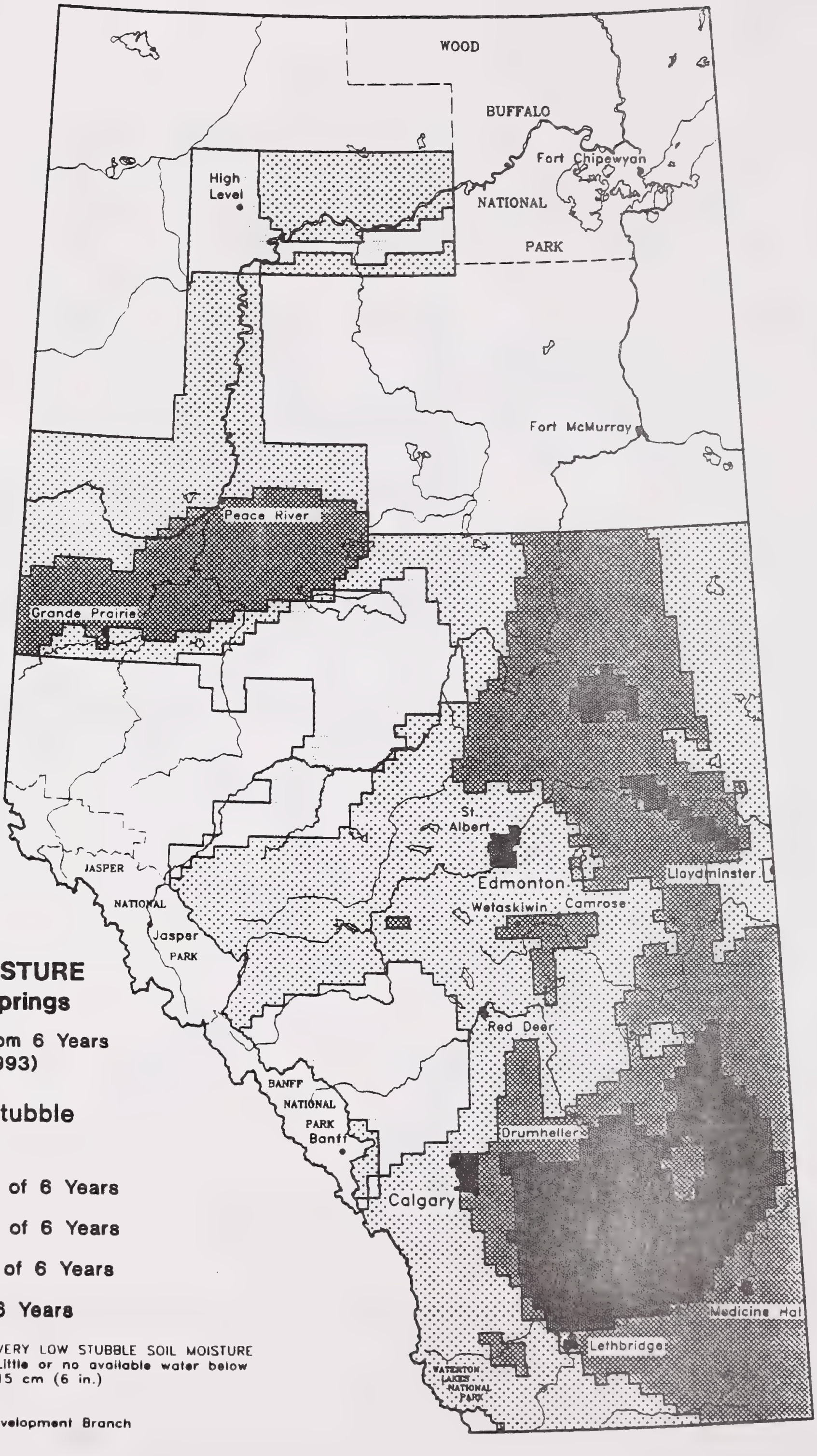
Low or Very Low Stubble Soil Moisture:

- 10 - 12 Years out of 12 Years
- 7 - 9 Years out of 12 Years
- 4 - 6 Years out of 12 Years
- 0 - 3 Years out of 12 Years

LOW STUBBLE SOIL MOISTURE
Subsoil moist to about 45 cm (18 in.)

VERY LOW STUBBLE SOIL MOISTURE
Little or no available water below 15 cm (6 in.)

Compiled by Conservation and Development Branch



Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

STUBBLE SOIL MOISTURE
Frequency of Dry Springs

Analysis of Information From 6 Years of Spring Data (1988 - 1993)

Low or Very Low Stubble Soil Moisture:

- 5 - 6 Years out of 6 Years
- 3 - 4 Years out of 6 Years
- 1 - 2 Years out of 6 Years
- 0 Years out of 6 Years

LOW STUBBLE SOIL MOISTURE
Subsoil moist to about 45 cm (18 in.)

VERY LOW STUBBLE SOIL MOISTURE
Little or no available water below 15 cm (6 in.)

Compiled by Conservation and Development Branch

CONSERVATION - DRYLAND SALINITY

A METHOD FOR PRODUCING SATURATED PASTE EQUIVALENT SALINITY MAPS FROM EM38 READINGS

D. Wentz, B. Read and C. Livergood[32]

INTRODUCTION

The Conservation and Development Branch is continuing to develop and refine the automated soils mapping program. Initially, a system was developed which allowed large tracts of land to be rapidly mapped for dryland salinity investigations. From this, contour maps were prepared which showed the gradient of soil salinity for a specific area. Next, a curve prediction technique evolved in which saturated paste equivalent electrical conductivities were determined from EM38 readings. The ability to produce salinity maps in a saturated paste format is the most recent development.

METHODS

Data collected in support of an existing research project near Crossfield, Alberta were used to develop this technique. The first step was to conduct an EM38 grid survey. During this operation, five soil sample sites were flagged. These sampling locations covered the range of EM38 values encountered during mapping. This number of sites appears to be sufficient to produce an accurate curve. More samples do not significantly improve the correlation. Mapping and subsequent sampling must be performed in areas with relatively uniform soil moisture. If large variations occur, the areas showing differences should be mapped and sampled separately.

Soil samples were collected in 30 cm increments to a depth of 150 cm. The samples were analyzed for EC and a mean 0-150 cm EC was determined. The mean EC and corresponding EM values were grouped and regression analysis was performed. A scatter diagram was produced and a linear curve ($Y=a+bx$) was plotted (Figure 1). The "a" and "b" values for the curve equation were determined and recorded. Each of the EM38 values recorded during gridding (z) were entered into the curve equation as the "x" value. These values should first be temperature corrected (z_1). From this, a set of saturated paste equivalent EC values were calculated (z_2). These values were used in conjunction with the gridding coordinates (x,y) to produce a computer generated soil salinity map in standard EC units.

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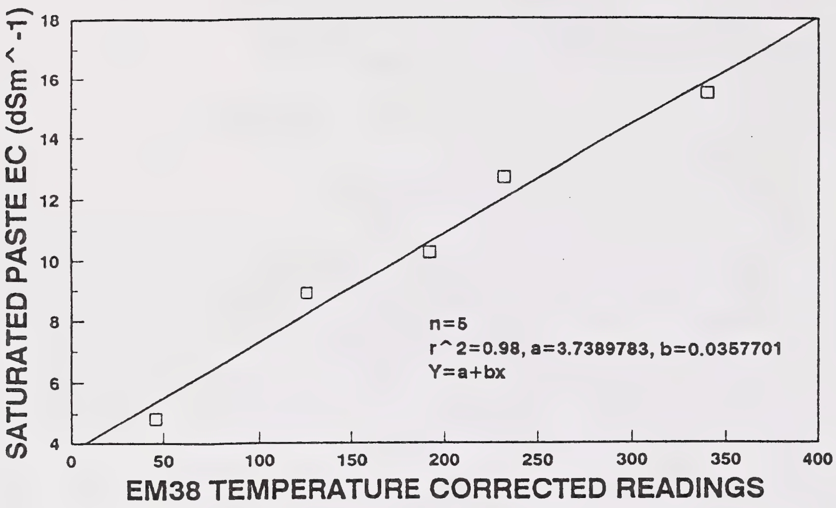

Figure 1. Electrical conductivity prediction curve and scatter diagram.

RESULTS

Table 1 presents a segment of an EM38 grid file. The table shows the "x" and "y" location coordinates and the corresponding EM values (z). The "z" column is temperature corrected by multiplying each value by a correction factor. In this instance, the soil temperature was 18.0 °C, requiring a multiplier of 1.1591. Each temperature corrected EM value (z_1) is next converted to a saturated paste equivalent (z_2). This is accomplished using the curve formula and corresponding inputs developed from regression analysis (Figure 1). That is, Y=a+bx,

where Y= saturated paste equivalent
a= 3.7389783
b= 0.0357701
x= temperature corrected EM value (z_1)

The saturated paste equivalent values (z_2) and their corresponding "x" and "y" coordinates are used to produce a salinity map (Figure 2). This is accomplished using a computer contouring program.

East - West Coordinates (m) (x)	North - South Coordinates (m) (y)	Uncorrected EM Values (z)	Temp. Corrected EM Values (z_1)	Saturated Paste Equiv. EC (dSm) (z_2)
0.00	10.00	37.27	43.20	5.28
0.00	12.00	37.10	43.00	5.28
0.00	14.00	42.79	49.60	5.51
0.00	16.00	45.64	52.90	5.63
0.00	18.00	46.33	53.70	5.66

Table 1. A portion of an EM38 grid file with temperature corrected and saturated paste equivalent values.

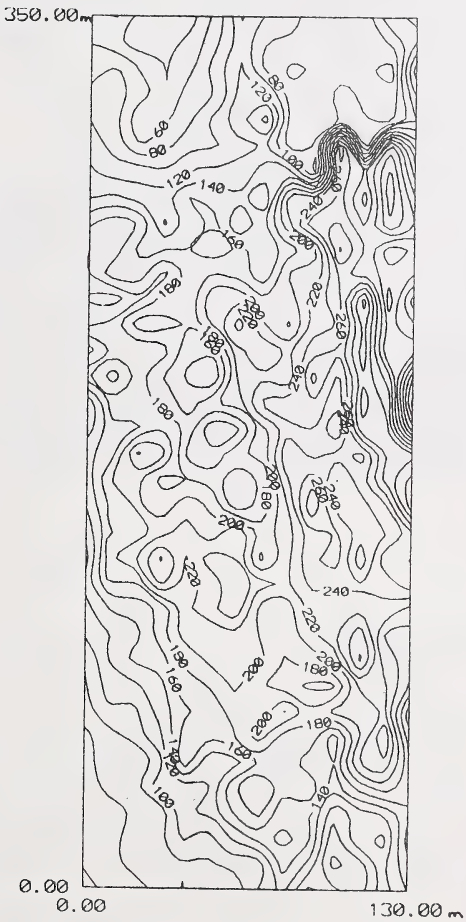

Figure 2a. EM38 temperature corrected contour map.

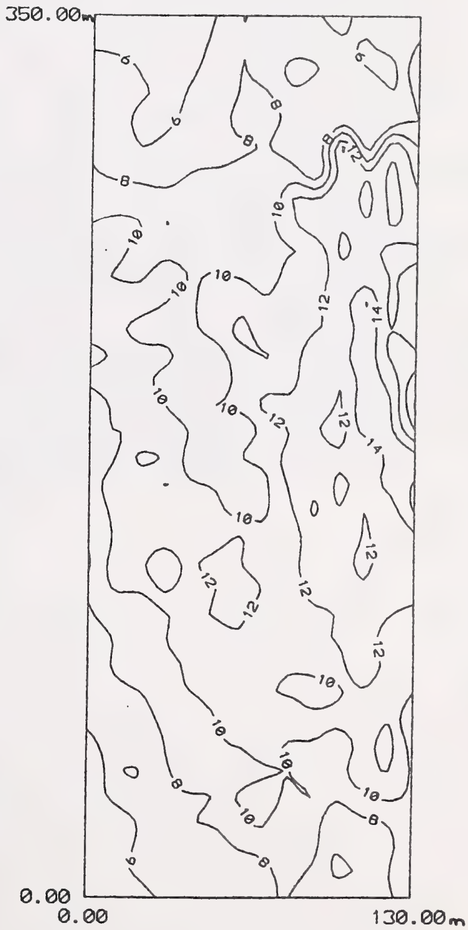

Figure 2b. Saturated paste equivalent EC contour map.

SW26-28-28 W4

CONCLUSION

It is possible to prepare saturated paste equivalent EC maps from EM38 surveys using the method described. Maps in EC units can be compared seasonally to denote change in salinity status. Maps prepared in EM units require correction for moisture and temperature.

More accurate cropping recommendations can also be made from these maps. Crop salt tolerance is based on EC units. Maps in these units make decisions on crop selection and placement much simpler. Using computer software packages, these maps can be produced using colour blending to display gradients in soil salinity.

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SOIL QUALITY EVALUATION PROGRAM
1993 STATUS REPORT - CARMANGAY, ALBERTA

D. Wentz and Bill Read[33]

INTRODUCTION

The National Soil Conservation Program (NSCP) was developed as a comprehensive program to monitor soil degradation in Canada. One component of the NSCP is the Soil Quality Evaluation Program (SQEP). This program was established as the first phase in the development of a Canadian soil quality monitoring program. To address the objectives of this program, a network of soil quality benchmark sites were established across the prairies to assess soil quality change.

The Conservation and Development Branch is monitoring three such sites in Alberta to provide data in support of this exercise. The information obtained will be used to develop a process-based model that simulates conditions encountered in the field. This report presents 1993 data from the Carmangay (Blackspring Ridge) site.

METHODS

The Carmangay site is located in the dark brown soil zone on the southwest quarter of section 12-13-23 W4. Soils at this site were characterized as clay loam textured of lacustrine origin. The surface expression was level and the slope class was 0.5 - 2.0% with a north-west aspect. The site was originally established as an Alberta Research Council study site, but was taken over as a benchmark monitoring site by the C&D Branch in 1993.

The monitoring parameters at this location included climate, hydrology, (Figure 2), groundwater salinity (Figure 3) and soil salinity (Figure 4). All will be reported on with the exception of the climate data. Soil and groundwater sampling took place in 1993 at four locations (sites 1-4) along a transect line, perpendicular to the topographic gradient (Figure 1).

RESULTS

Hydrology

Groundwater movement was monitored from May to October during 1993. The upslope site, #1, was the only location with piezometric installations. The remaining sites, 2-4, contained water table wells only. At site #1, groundwater levels, measured in the well increased throughout the season. The deepest level was recorded in May (2.72m) with the most shallow situation occurring in October (1.45m) The 33ft piezometer was stable through May, showing downward movement in July. A rapid increase in piezometric head occurred through August and September. Values ranged from a low of 3.36m in July to 0.50m in October. The 98ft piezometer demonstrated a discharge situation throughout most of the season, becoming as shallow as 0.29m. The 233ft piezometer was at the surface continually.

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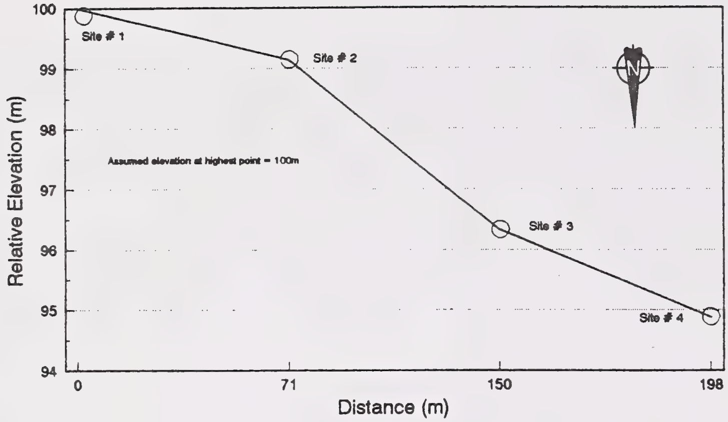

Figure 1. Data collection sites along transect line. (Blackspring Ridge Site)

At site #2, groundwater levels declined in mid May (3.67m), then recovered to a stable situation (2.50m) throughout the summer. Groundwater movement at discharge sites #3 and #4 paralleled each other. At both sites, water tables were less than one metre and any seasonal fluctuations which occurred reflected precipitation events. Levels ranged from 0.2 to 0.6m through the spring and summer months. Water tables began to increase in September and October with declining crop use and increasing rainfall.

Groundwater Salinity

Groundwater was sampled for salinity content in May, July and October, 1993. The electrical conductivity of the groundwater showed little change from spring to fall. The highest levels at each site were recorded in July. The most saline groundwater was found at site #4, where mean seasonal EC was 39.7 dSm. The next most saline groundwater was at site #3, 26.4 dSm; site #1, 19.0 dSm; and site #2, 13.6 dSm.

Soil Salinity

Soil was sampled at each site in 30cm increments to a depth of 120cm on three occasions in 1993 (May, July and October). Soils at sites #1 and #2 were moderately saline. At site #1, mean 0-120cm soil EC ranged from a high of 4.17 dSm in May to a low of 1.00 dSm in July. At site #2, soil EC increased throughout the season, from 3.35 dSm in May to 8.44 dSm in October. Soils at sites #3 and #4 were highly saline. Electrical conductivity at these sites increased from spring to summer, stabilizing into the fall. Mean seasonal EC at site #3 was 20.24 dSm; 27.34 dSm at site #4.

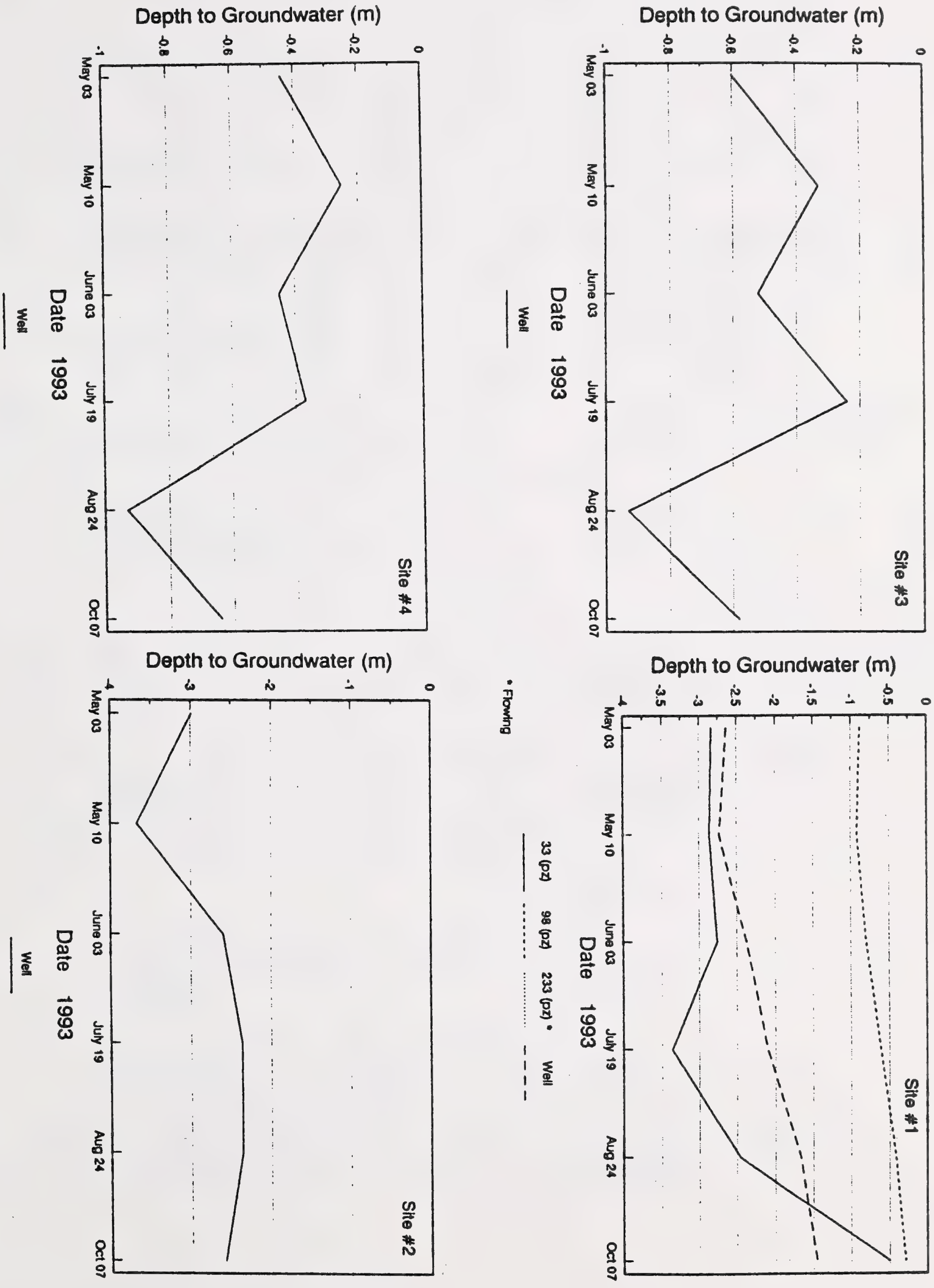

Figure 2. Hydrographs.

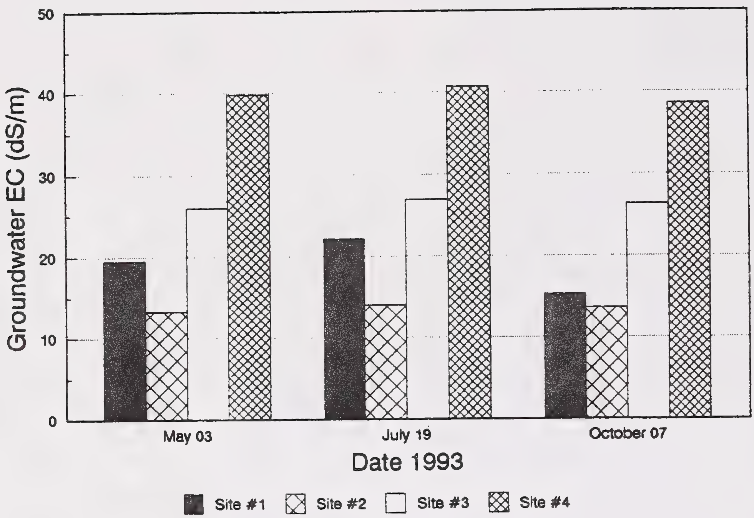

Figure 3. Groundwater salinity.

CONCLUSION

Monitoring will continue at each SQEP site for the next few years. Data collected will document trends in the salinity status and will provide inputs for modelling activities. Ultimately, this information can be used to predict changes in soil quality due to salinization.

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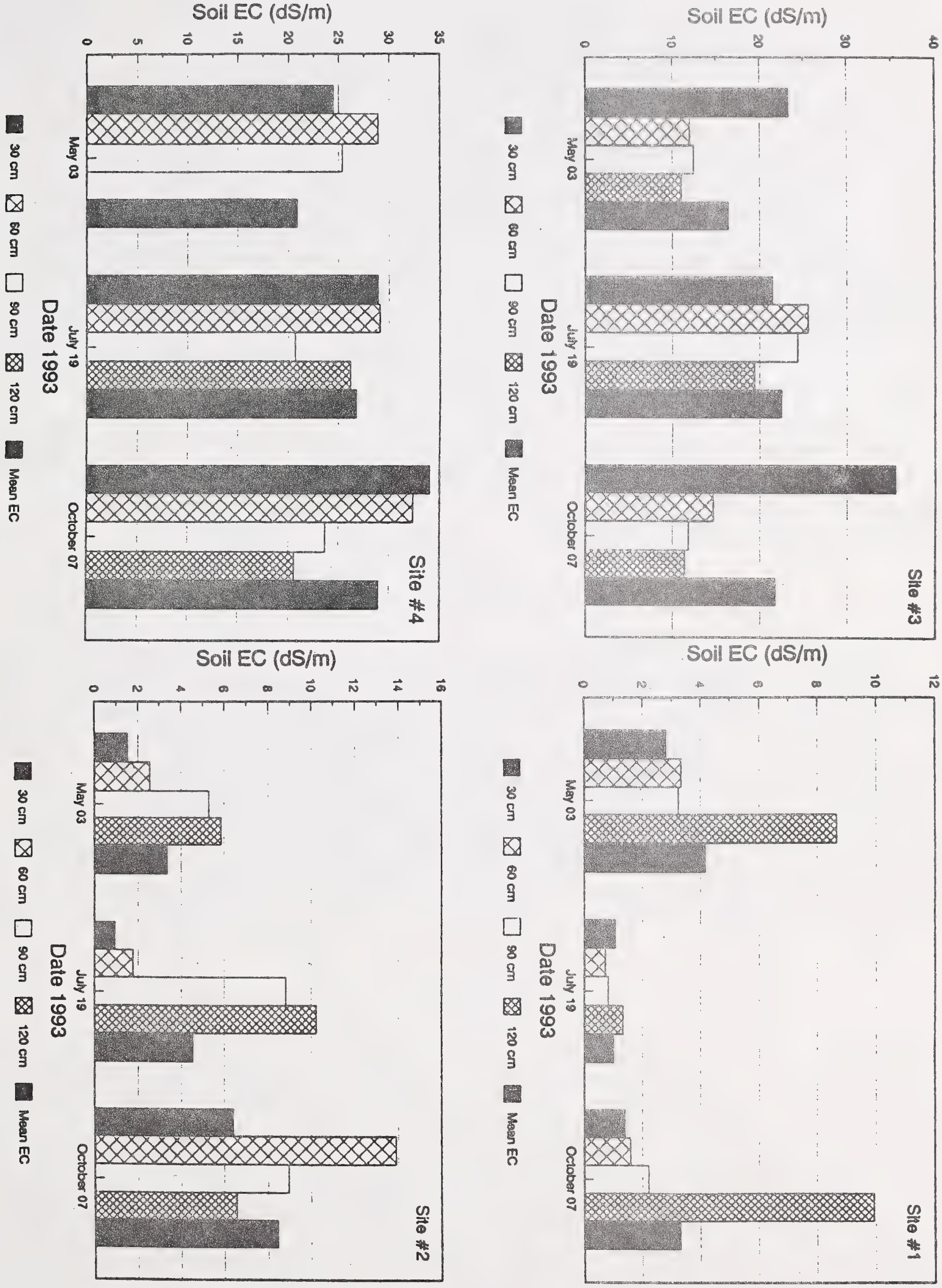

Figure 4. Soil salinity.

SOIL QUALITY EVALUATION PROGRAM
1993 STATUS REPORT - FORESTBURG, ALBERTA

D. Wentz and B. Read[34]

INTRODUCTION

The National Soil Conservation Program (NSCP) was developed as a comprehensive program to monitor soil degradation in Canada. One component of the NSCP is the Soil Quality Evaluation Program (SQEP). This program was established as the first phase in the development of a Canadian soil quality monitoring program. To address the objectives of this program, a network of soil quality benchmark sites were established across the prairies to assess soil quality change.

The Conservation and Development Branch is monitoring three such sites in Alberta to provide data in support of this exercise. The information obtained will be used to develop a process-based model that simulates conditions encountered in the field. This report presents 1993 data from the Forestburg site.

METHODS

The Forestburg site is located in the black soil zone on the southwest quarter of section 4-41-15 W4. Soils at this site were characterized as clay loam textured of morainal origin. The surface expression was hummocky and the slope class was 5.0-9.0% with a west aspect. The site was originally established as a Ph.D. research site, but was taken over as a benchmark monitoring site by the C&D Branch in 1993.

The monitoring parameters at this location included climate, hydrology (Figure 2), groundwater salinity (Figure 3) and soil salinity (Figure 4). All will be reported on with the exception of the climate data. Soil and groundwater sampling took place in 1993 at five locations (175, 177, 181, 200, 201) along a transect line, perpendicular to the topographic gradient (Figure 1).

RESULTS

Hydrology

Groundwater levels were monitored in all wells and piezometers from April to October, 1993 (Figure 1). Site #175 represents the most upslope location. Site #201 is the lowest topographic position. At site #175, groundwater levels were below the depth of the 6.10m well and no readings were recorded. Piezometers at 5.70m, 8.04m and 10.50m read essentially the same throughout the season, at about 5.40m. The deep piezometer at site #175 was also relatively stable, but showed slight downward movement through mid summer before increasing significantly in August and September. Values for the 15.20m piezometer ranged from a low of 11.43m in July to a high of 9.02m in October. At site #177,

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[34] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Albert. T1J 4C7.

piezometers at 3.47m and 4.31m showed upward movement in the spring. The 6.05m piezometer showed the opposite. From June through October head values in this piezometer were stable around 3.0m.

At site #181, the most shallow piezometers (3.43m and 3.50m) and the well had similar readings. All showed downward movement from May through June. Movement was then upward, peaking in July at 0.53m. This followed 336mm of rainfall. Levels fell again through August and September. The 5.45m piezometer showed stable spring values, then a gradual increase from June (2.55m) through October (1.52m).

Piezometric head and water table values at sites #200 and #201 were very similar. Groundwater movement was in discharge situation in the spring, followed by a trend toward recharge into summer. Significant mid summer rainfall raised groundwater depths as shallow as 0.66m in late July. Levels then steadily dropped into October.

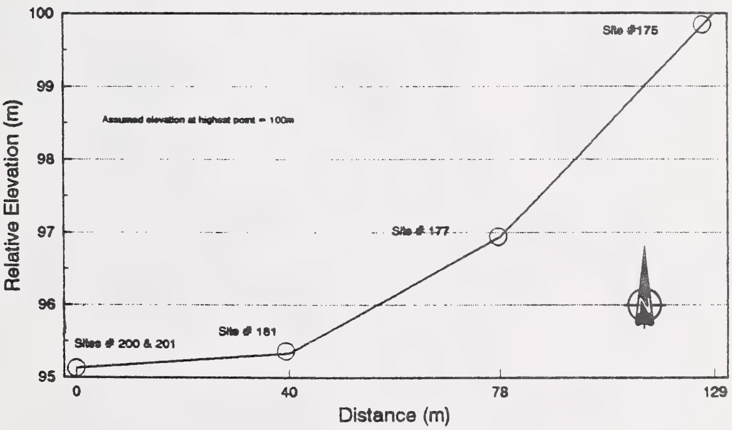

Figure 1. Data collection sites along transect line. (Forestburg Site)

<u>Groundwater Salinity</u>

Groundwater was sampled in April, June and October of 1993 at sites #177, #181 and #200. Because of the close proximity of sites #200 and #201, one well was centrally installed to service both sites. Groundwater EC for these sites is reported as site #200. Groundwater at site #175 was not sampled because levels were consistently below the depth of the well. Groundwater at site #177 showed a slight seasonal increase in EC, ranging from 9.50 dSm in April to 10.70 dSm in October. At site #181, groundwater salinity was much higher, averaging 35.05 dSm from June to October. Groundwater EC at site #200 declined from a high of 19.20 dSm in the spring to a low of 8.30 dSm in the summer. EC increased again in the fall to 11.94 dSm.

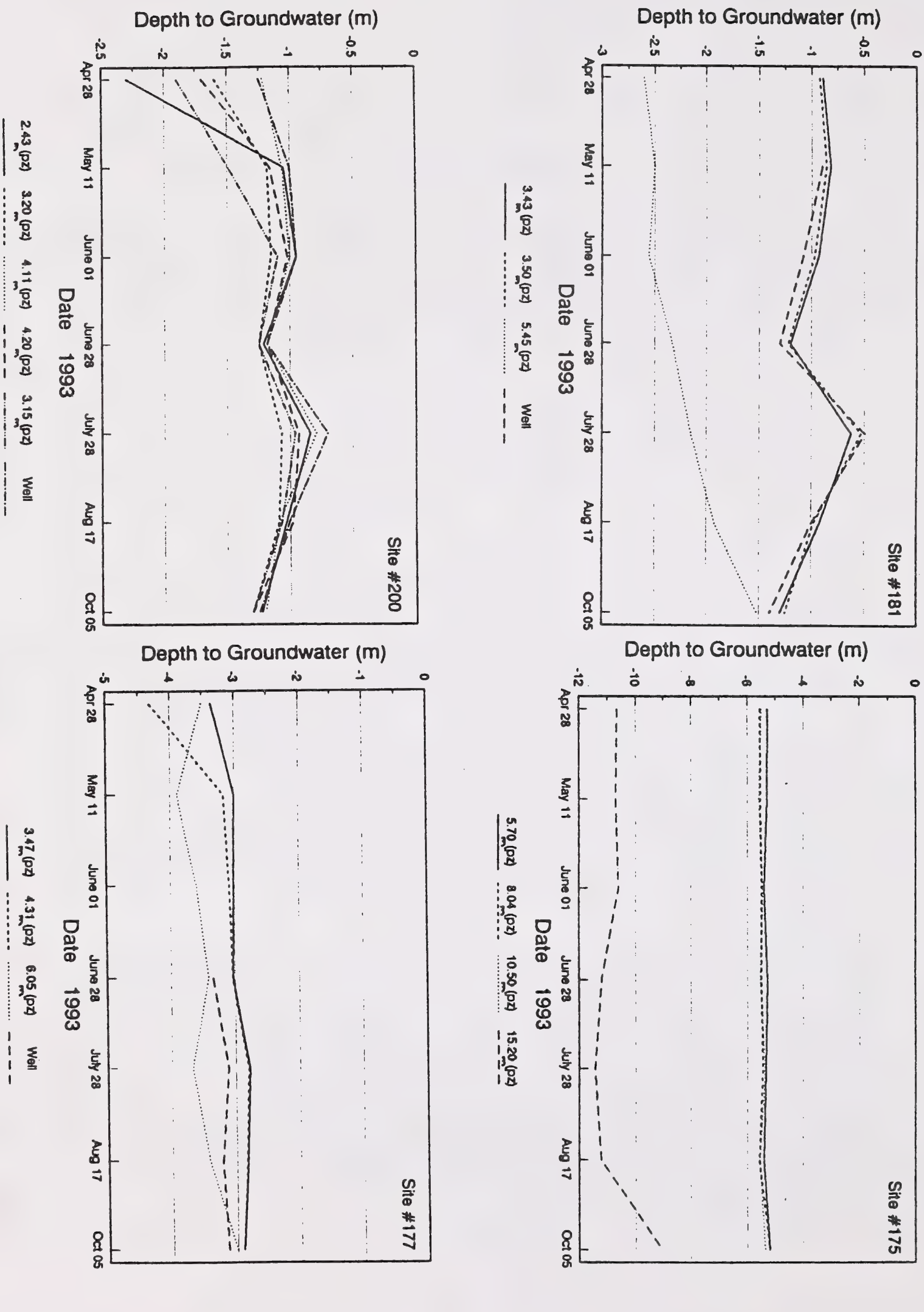

Figure 2. Hydrographs.

Soil Salinity

Mean 0-120cm soil EC at all four sites showed a similar pattern. Soil EC increased significantly from April to June then declined in October. The exception was site #200 where EC increased in October. Levels at site #175 ranged from 2.34 dSm to 4.86 dSm; 0.66 dSm to 5.34 dSm at site #177; 7.52 dSm to 11.49 dSm at site #181; and 5.73 dSm to 11.59 dSm at site #200.

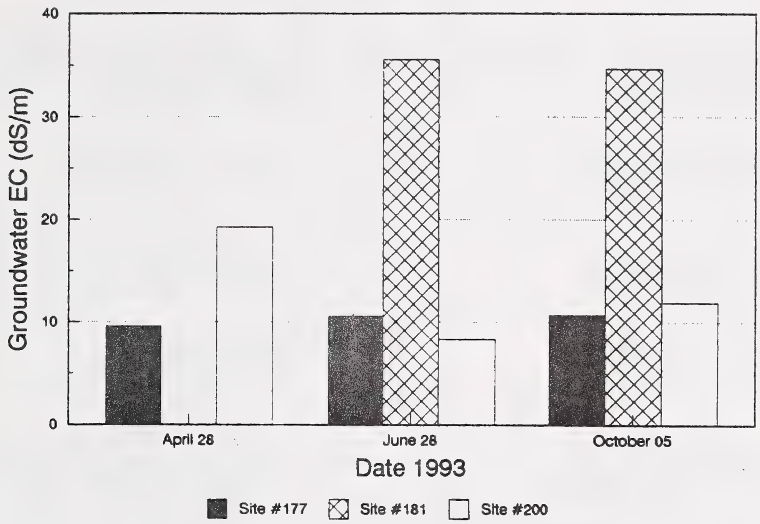

Figure 3. Groundwater salinity.

CONCLUSION

Monitoring will continue at each SQEP site for the next few years. Data collected will document trends in the salinity status and will provide input for modelling activities. Ultimately, this information can be used to predict changes in soil quality due to salinization.

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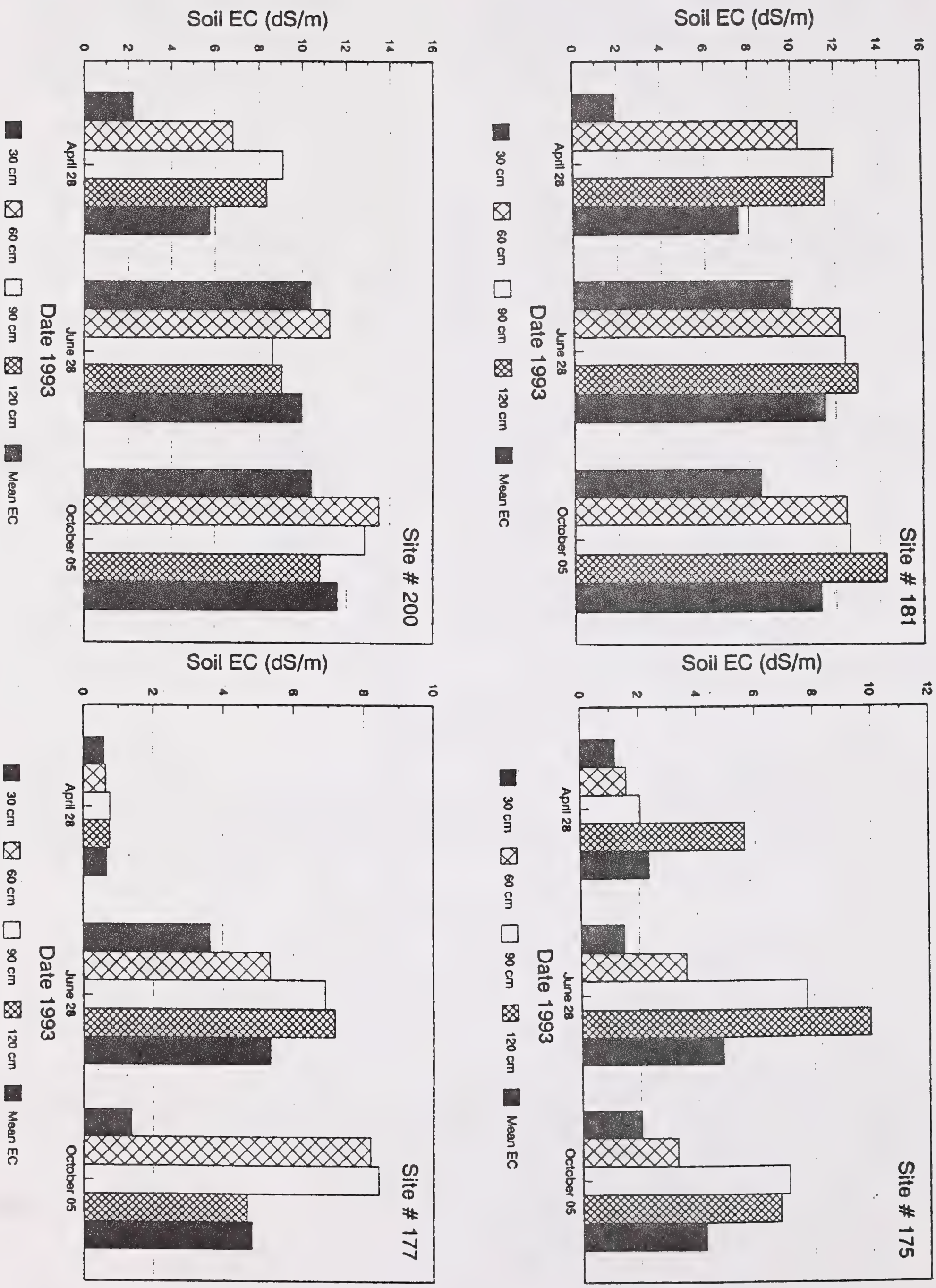

Figure 4. Soil salinity.

SOIL QUALITY EVALUATION PROGRAM
1993 STATUS REPORT - CROSSFIELD, ALBERTA

D. Wentz and Bill Read[35]

INTRODUCTION

The National Soil Conservation Program (NSCP) was developed as a comprehensive program to monitor soil degradation in Canada. One component of the NSCP is the Soil Quality Evaluation Program (SQEP). This program was established as the first phase in the development of a Canadian soil quality monitoring program. To address the objectives of this program, a network of soil quality benchmark sites were established across the prairies to assess soil quality change.

The Conservation and Development Branch is monitoring three such sites in Alberta to provide data in support of this exercise. The information obtained will be used to develop a process-based model that simulates conditions encountered in the field. This report presents 1993 data from the Crossfield site.

METHODS

The Crossfield site is located in the black soil zone on the southwest quarter of section 26-28-28 W4. Soils at this site were characterized as loam textured of morainal origin. The surface expression was undulating and the slope class was 2.0 - 5.0% with an east aspect. The site was originally established as a dryland salinity investigation site, but was taken over as a benchmark monitoring site by the C&D Branch in 1993.

The monitoring parameters at this location included climate, hydrology, (Figure 2), groundwater salinity (Figure 3) and soil salinity (Figure 4). All will be reported on with the exception of the climate data. Soil and groundwater sampling took place in 1993 at four location (1831 - 1843) along a transect line, perpendicular to the topographic gradient (Figure 1).

RESULTS

Hydrology

Groundwater levels at site 1831 (discharge site) showed a general increase throughout 1993. Groundwater rose from a low of 1.7m in January to a high of 0.49m in August. A trend towards deeper levels in mid season was reversed with a total of 215mm of rainfall received on site in July and August. Piezometers demonstrated a discharge situation through April, recharge in June and discharge again through July and August. Piezometric head dropped through September with the exception of the 8.53m piezometer.

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[35] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Alberta. T1J 4C7.

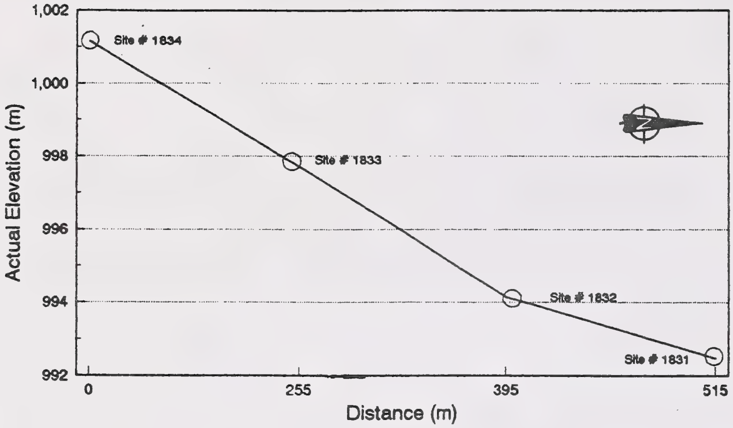

Figure 1. Data collection sites along transect line. (Crossfield Site)

Groundwater levels were relatively constant at site 1832 throughout the season. Typical spring discharge and summer-fall recharge occurred. Water table levels and piezometric heads showed no significant fluctuations.

Groundwater levels were also stable at sites 1833 and 1834 (upslope recharge sites). No significant fluctuations or trends in water levels or piezometric heads were noted.

Groundwater Salinity

The salinity status of the groundwater was determined on three occasions in 1993 (January, July and October). At all sites and on all occasions, the salinity of the groundwater remained relatively unchanged. Mean groundwater electrical conductivity at site 1831 was 11.56 dSm; 1.99 dSm at site 1832; 1.82 dSm at site 1833; and 1.66 dSm at site 1834.

Soil Salinity

Soil salinity at depth was also determined on three occasions in 1993. Sampling in April, July and October at site 1831 showed a general decline in mean 0-120cm soil salinity. Levels ranged from 11.22 dSm in the spring to 9.74 dSm in the fall. At site 1832, mean EC was lowest in July, 7.48 dSm and highest in October, 8.42 dSm. Soil salinity at the recharge sites 1833 and 1834 was considerably lower. Mean seasonal EC at 1833 was 2.90 dSm; 0.69 dSm at 1834 (July and October data only; erroneous data for April). At site 1833 values ranged from a high of 3.47 dSm in October to a low of 2.47 dSm in July. Salinity at 1834 declined from 0.79 dSm in July to 0.60 dSm in October.

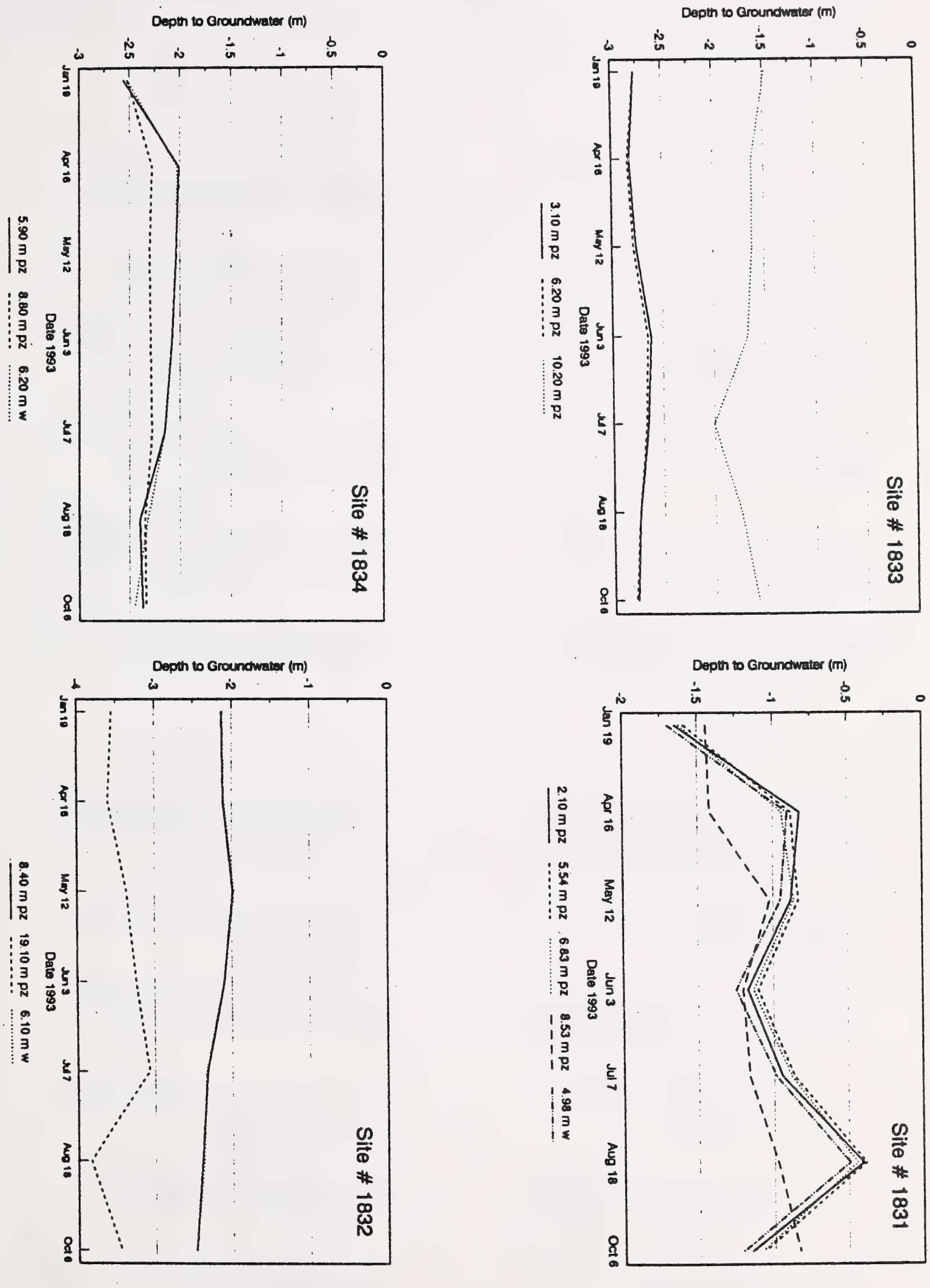

Figure 2. Hydrographs.

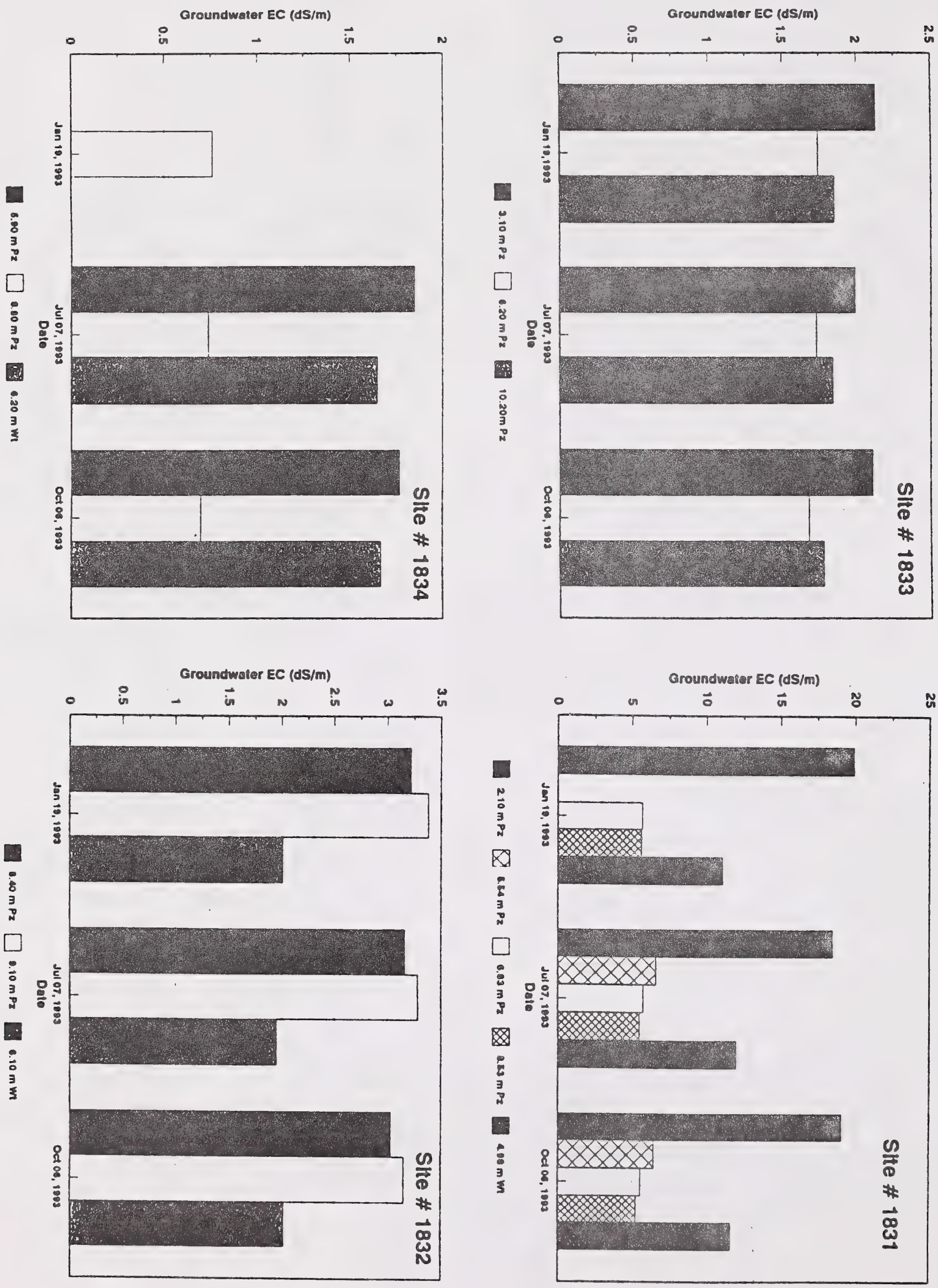

Figure 3. Groundwater salinity.

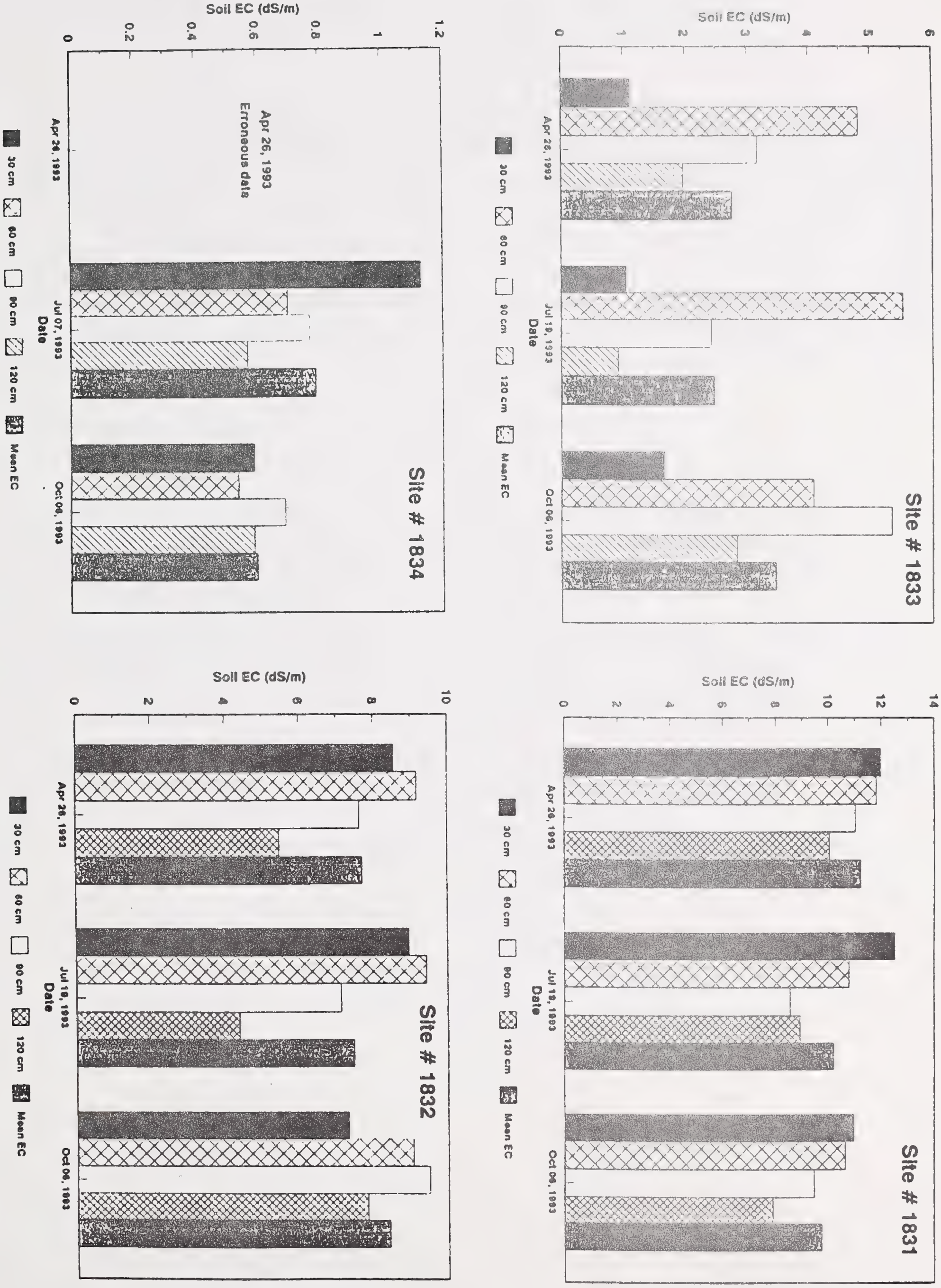

Figure 4. Soil salinity.

CONCLUSION

Monitoring will continue at each SQEP site for the next few years. Data collected will document trends in the salinity status and will provide inputs for modelling activities. Ultimately, this information can be used to predict changes in soil quality due to salinization.

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CHEMICAL QUALITY OF PLANTS, SOILS AND SHALLOW GROUNDWATERS OF SALINE SEEPS IN ALBERTA, 1990-1993

D. Wentz and B. Read[36]

INTRODUCTION

The sampling phase of this four year study concluded in 1993. The intent of the project was to determine trace element levels in plants, soils and groundwaters within saline seeps in Alberta. Saline seeps by their hydrologic nature may accumulate and concentrate many of these chemicals. Toxic levels of inorganic chemicals present in these soils and shallow groundwaters may be accumulating in the vegetation. If these plants are fed, toxic levels of these chemicals may further concentrate in livestock. If this is in fact the case, there may be serious implications for human nutrition.

METHODS

From 1990 to 1993, a total of 212 dryland salinity sites were investigated. Of these, 102 were deemed suitable and were sampled for plants, soil and groundwater. Sites were located in saline areas throughout Alberta, predominately in the south and south central regions of the province (Figure 1).

Groundwater samples destined for trace element analysis were filtered in the field through a 0.45 micrometer filter. Samples were acidified, packed in ice and transported to the lab where they were stored at 4°C awaiting analysis. The remaining portion of the groundwater sample was transported on ice to the lab within 48 hours for determination of EC, pH, nitrates, carbonates and bicarbonates. Plant samples were oven dried at 65°C for 24 hours, placed in plastic bags and stored in a deep freeze until analyzed. Soil samples were air dried and stored.

Trace elements in plant, soil and groundwater samples were determined by inductively coupled plasma (ICP). Analysis was performed in the Soil and Animal Nutrition Lab, Alberta Agriculture, Food and Rural Development, Edmonton. Trace elements in soil and water samples were also determined by atomic absorption techniques in the laboratory of the Land Evaluation and Reclamation Branch, Alberta Agriculture, Food and Rural Development, in Lethbridge. The following chemical constituents were determined in plant, soil and water samples: Ca, Mg, Na, K, SO4, NO3, F, Cl, Al, Cd, Cu, Hg, Fe, Mn, Mo, Zn, Pb, Co, As, Se, P, S, and B.

36 Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Alberta T1J 4C7

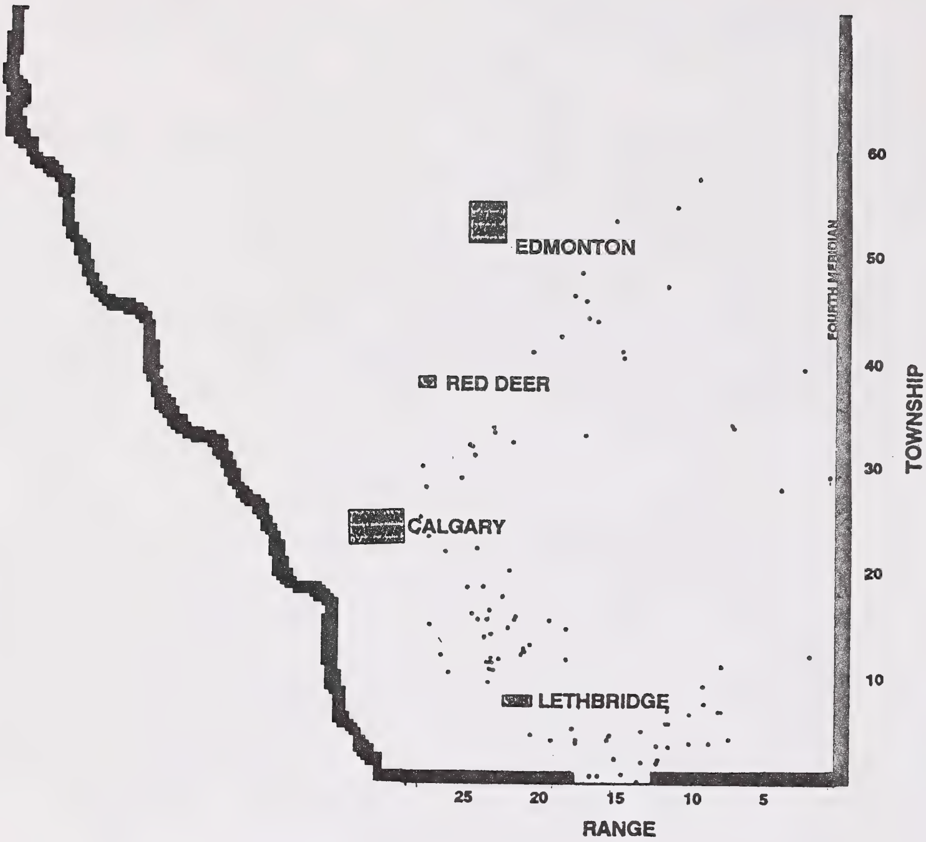

Figure 1. Sampling locations 1990 - 1993.

RESULTS

Presentation of trace element data is based on the percentage of sites containing element levels equal to or greater than recommended guidelines. Table 1 presents trace element levels in groundwater. Table 2 shows trace element levels in plants. Of the three materials sampled, groundwater has well documented quality guidelines. Feed quality guidelines are somewhat limited. Soil guidelines are incomplete. In previous years of this study, irrigation water quality and livestock water quality limits were used as soil quality guidelines. This did not provide an accurate representation of acceptable soil trace element levels. Soils data will not, therefore, be presented at this time.

Limits for trace elements in groundwater are based on livestock drinking water guidelines (Environment Canada). Limits for plants come from mineral tolerance of domestic animals guidelines (National Academy of Sciences). Within the livestock drinking water quality and feed quality guidelines are some elements which do not yet have adequate quality guidelines developed. In particular, manganese and iron in livestock water and aluminum and boron in feed. Analysis results for these elements are not presented. In

addition, the cations calcium, magnesium, sodium and potassium and the anions sulphate, chloride and nitrate are not considered trace elements and their levels are not presented either.

Table 1. Chemical quality of groundwater.

ELEMENT	MAX. RECOMMENDED LIMIT (ppm)	PERCENT OF SITES > RECOMMENDED LIMITS	NO. OF SITES SAMPLED/WITH AVAILABLE RESULTS
Fluorine	2.00	63	102
Boron	5.00	2	102
Cadmium	0.02	38	102
Lead	0.10	17	102
Arsenic	0.50	28	72 *
Mercury	0.003	23	57 **
Selenium	0.05	86	42 **

* no analysis results available in 1990
** no analysis results available in 1990 and 1992
*** no analysis results available in 1990 and 1993

Table 2. Chemical quality of plants.

ELEMENT	MAX. RECOMMENDED LIMIT (ppm)	PERCENT OF SITES > RECOMMENDED LIMITS	NO. OF SITES SAMPLED/WITH AVAILABLE RESULTS
Iron	1000	5	102
Mercury	2	47	57 **
Cadmium	0.5	52	102

** No analysis results available in 1990 and 1992.

CONCLUSION

Toxic levels of certain trace elements are present in saline seeps of Alberta. These elements occur naturally, but their levels may be enhanced by the topographic position of the seep or by hydrological flow patterns involved in the maintenance of the seep. Selenium and fluorine in particular are prevalent in groundwater. Mercury and cadmium are common in plants.

Vegetative controls are being recommended as a reclamation measure in saline areas. Some of these plants may be accumulating trace elements. The next phase of this study will attempt to determine which species may be more likely to concentrate these elements. From this information vegetative control recommendations may become more species selective.

ACKNOWLEDGEMENTS

The authors wish to thank Dan Heany and staff of the SANL (Soils Branch) Edmonton; and Lab Services (LEAR Branch) Lethbridge, for their analytical assistance. Also thanks to Allan Plesko for compiling the data.

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SALT TOLERANT GRASS VARIETY DEMONSTRATION

D. Wentz and B. Read[37]

INTRODUCTION

The Conservation and Development Branch is continuing to assess the performance of salt-tolerant grass and forage varieties. These crops are used for the vegetative control of dryland salinity. Demonstration plots set up to observe varietal performance are also being monitored to provide moisture use and yield data. Findings from one such demonstration in the Trochu, Alberta area are presented in this report.

METHODS

The study site is located in the southeast quarter of section 31-33-23-W4, approximately 4 km north of Trochu, Alberta. The site was chosen for two reasons. First, the area had a gradient of soil salinity on which to demonstrate the salt tolerance of the grass and legume varieties. Secondly, it's location adjacent to a major highway made it an excellent site for a demonstration.

The site was first examined in 1992 as part of a Dryland Salinity Investigation. At this time an automated EM38 survey was conducted to determine the salinity status of the soil (Figure 1). Water table wells were installed at the four corners of the study area to allow for monitoring the groundwater movement. The water from each well was sampled and analyzed for EC, pH, SAR, cations and anions.

Thirty, 3 m by 91 m strips were seeded to eight varieties of grass and two varieties of alfalfa. Each variety was replicated three times and arranged in a randomized block design (Figure 1). The varieties used were as follows:

1. Smooth brome
2. Altai wildrye
3. Garrison creeping foxtail
4. Shoshone beardless wildrye
5. Crested wheatgrass
6. Tall wheatgrass
7. Reed canary grass
8. Pubescent wheatgrass
9. Drylander alfalfa
10. Beaver alfalfa

* Forage and grass mix

The plots were seeded at rates recommended in the Alberta Forage Manual. The adjacent area immediately surrounding the plots was seeded to a grass and alfalfa mix. Only data collected from the grass plots will be reported at this time.

In preparation for seeding, Roundup herbicide was applied to the plot area. Fertilizer application consisted of sixty pounds per acre of 11-52-0, applied with the seed.

A 1.2 m neutron probe access tube was centrally installed in each plot to allow for the

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measurement of soil moisture. During tube installation, soil samples were collected from each hole in 30 cm increments to a depth of 1.5 m. Samples were analyzed for EC, pH, SAR, cations, anions and particle size. A tipping bucket rain gauge, connected to a data logger was set up on site to continually measure and record precipitation.

Routine data collection took place on a monthly basis for soil moisture content, groundwater movement and crop observations. Readings began in August, 1992 and concluded in September. Data collection started again in April 1993 and ended in August. Yield sampling was performed in June, 1993 at three 0.25 m^2 locations within each plot.

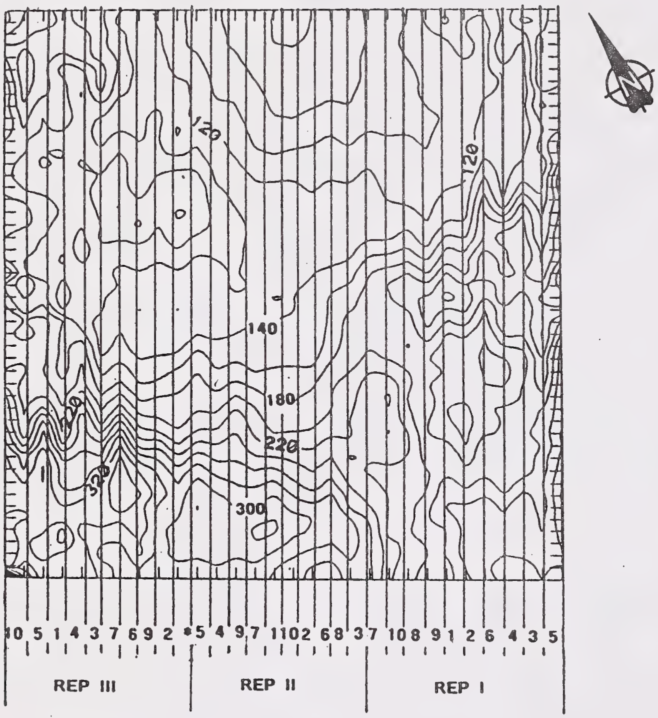


Figure 1. EM38 soil salinity map and plot plan.

RESULTS

The first year of this study, 1992, involved the layout and instrumentation of the plots, and the seeding and establishment of the grasses. In 1993, data collection began in earnest, providing soil water use and yield data for each grass variety.

Graphs depicting mean seasonal soil moisture levels (average of three reps) for each grass are presented in Figures 2a and 2b. In all cases, soil moisture content at 30 cm showed a seasonal decline in the second year. This reflects shallow rooting and increased evapotranspiration from the surface soils. Over time, deeper rooting should result in an

increased extraction of soil moisture from greater depths. Soil moisture in the 60 - 120 cm range remained relatively constant throughout both seasons, with the exception of the Crested Wheatgrass and Altai Wildrye plots. These two varieties showed some moisture extraction from the 60 cm depth.

In 1993, Smooth Brome extracted the largest volume of soil water of the eight grasses grown. Pubescent Wheatgrass and Shoshone Beardless Wildrye used the least. Seasonal precipitation totalled 33.2 mm (April 15 - July 6). The average depth to groundwater was 1.24 m (Figure 3).

Table 1 lists the mean seasonal soil moisture deficit, yield and soil EC for each variety. Yield samples were collected at three locations within each plot. Reported values are from the samples taken nearest to each soil moisture monitoring site. Similarly, EC values are calculated from EM griding, also in this vicinity.

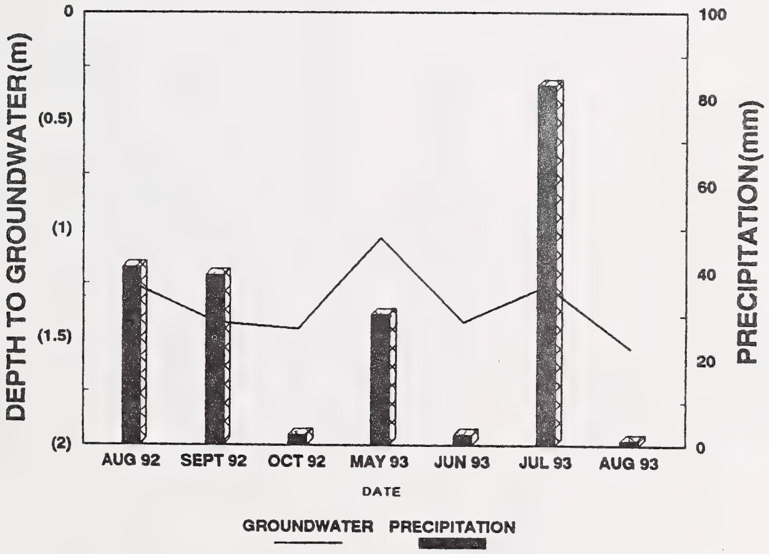


Figure 3. Seasonal groundwater movement and precipitation.

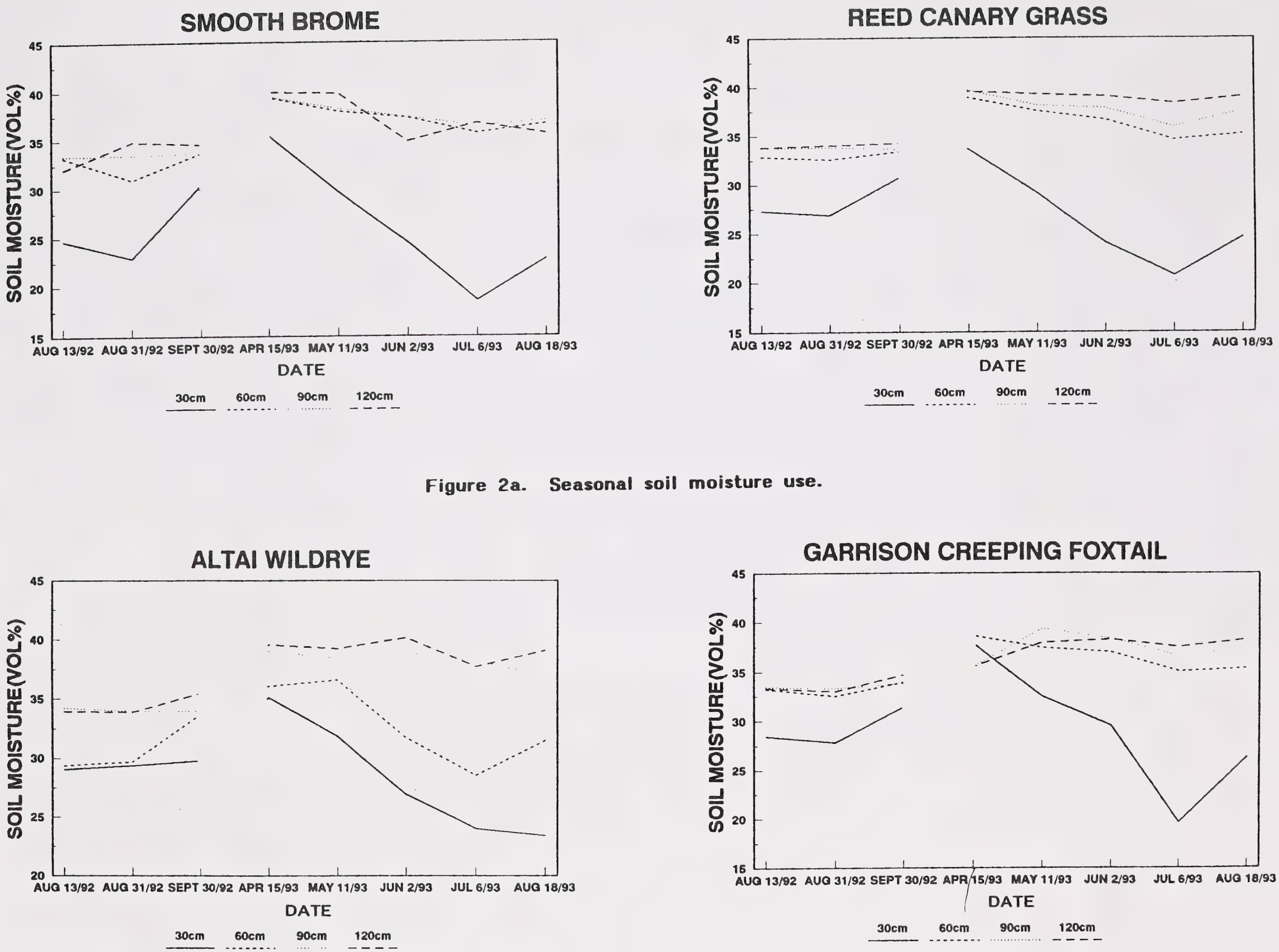
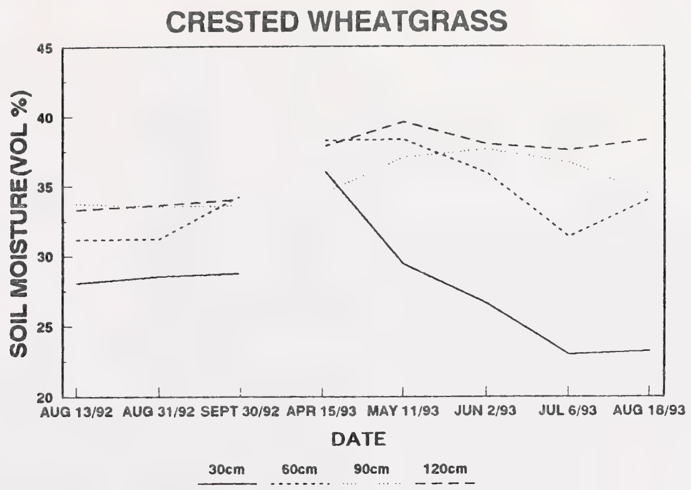


Figure 2a. Seasonal soil moisture use.



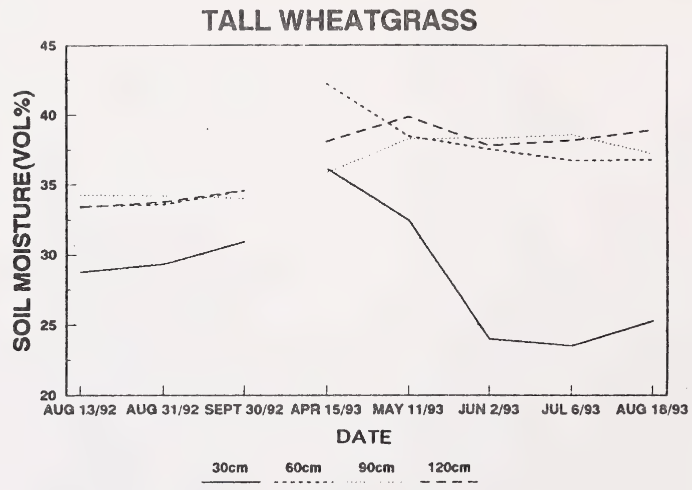
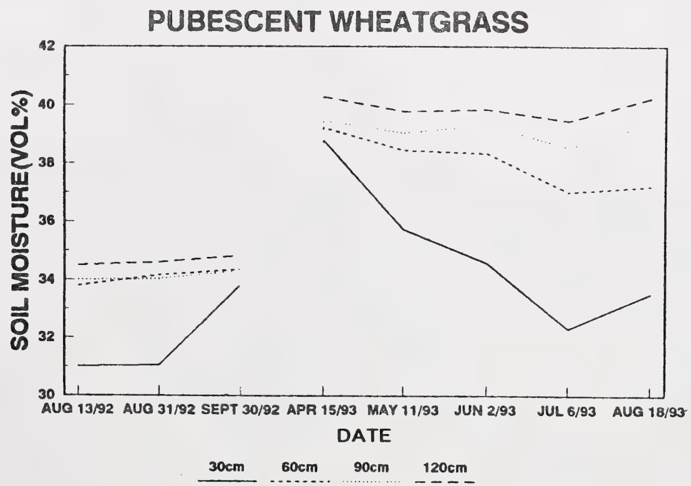


Figure 2b. Seasonal soil moisture use.



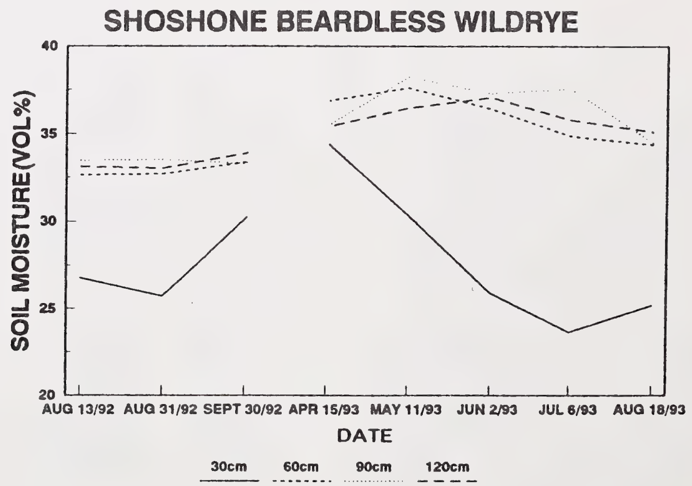


Table 1. Average soil moisture deficit and yield of eight grass varieties with the accompanying plot mean soil electrical conductivity.

VARIETY	SEASONAL MOISTURE DEFICIT (vol pct)	AVERAGE YIELD (gms/0.25m^2)	PLOT SOIL EC (dSm)
Smooth Brome	-26.9	118.2	12.19
Reed Canary Grass	-22.4	65.8	10.95
Altai Wildrye	-21.4	16.2	11.53
Garrison Creeping Foxtail	-18.9	85.2	11.95
Crested Wheatgrass	-18.2	94.5	12.44
Tall Wheatgrass	-15.3	27.5	11.71
Shoshone Beardless Wildrye	-10.4	21.5	11.79
Pubescent Wheatgrass	-10.4	115.0	12.48

CONCLUSION

When reclaiming salt-affected land, the reduction of groundwater levels in recharge areas is important. This can be accomplished with deep rooted forages. In discharge areas, high levels of salinity make the establishment of a crop difficult. Salt tolerant grasses are usually best suited for these areas.

This project demonstrated the performance of eight different grass varieties on a gradient of saline soil. After one full season of study, Smooth Brome extracted the largest volume of soil moisture. It also produced the greatest dry matter yield. Study will continue at this site in 1994.

ACKNOWLEDGEMENT

The authors wish to express their gratitude to Mr. Michael Frere for providing the use of his land to conduct this project. Also, to Mr. Ken King, District Agriculturalist, Three Hills, for his efforts in yield sampling, site maintenance and overall coordination of on-site activities; and to Mr. Scott Meers, Region II Soil Conservation Coordinator for performing the seedling plant counts.

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ROOTING DEPTH AND SOIL WATER USE OF TEN VARIETIES OF ALFALFA IN SOUTHERN ALBERTA

D. Wentz, B. Read and V. Sawchuk[38]

INTRODUCTION

Past studies by the authors have indicated that alfalfa performs differently in one soil zone as opposed to another. Two years of investigation in the dark brown soils determined an alfalfa performance ranking considerably different than in the brown soils. Alfalfa is recommended as a vegetative control for dryland salinity in saline areas throughout the province. It is therefore, important to select a variety which is best suited for the area in question. Findings from these study should serve this end. This report presents results from two seasons of study in the brown soils.

METHODS

The study site is located on private land near Bow Island, Alberta. An existing alfalfa variety trial (87-F003-1) was used to conduct this project.

Ten alfalfa varieties were replicated three times providing a total of thirty alfalfa plots. In addition, three fallow treatments were created (Table 1). In each plot a 4 m deep access tube was installed. This allowed soil moisture to be read at depth using the neutron scatter technique. At the four corners of the plot area, a water table well was located to monitor groundwater movement. A rain gauge was also situated on site. Bi-weekly data collection began in April and continued through September of each year (1992, 1993).

The soil in each plot was sampled and analyzed for particle size and routine chemistry. Results indicated a generally uniform clay loam textured soil with a mean 0 -150 cm electrical conductivity of 4.7 dSm. An EM38 survey was performed in the plot area to further determine soil salinity levels.

Rooting depth and soil water use for each alfalfa variety was determined from a graph of soil moisture versus depth for each alfalfa cultivar and fallow plot (Figure 1). Rooting depth was determined on the graph by the intersection of the alfalfa and fallow curves. Soil water use was calculated as the area between the two curves from a depth of 25 cm to the depth of rooting. Results are reported as mean yield, rooting depth and soil water use of three reps, averaged for two years. Mean values of soil moisture for the three fallow plots were used in all moisture use and rooting depth determinations. At the completion of the study, each plot was cored and visual examination for roots took place.

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[38] Conservation and Development Branch, Irrigation and Resource Management Division, Alberta Agriculture, Food and Rural Development, Agriculture Centre, Lethbridge, Alberta

Table 1. Ten alfalfa cultivars used in this study.

VARIETY	TYPE	ROOTING TYPE	HARDINESS
Rambler	Dryland	Creeping	Excellent
Spredor II	Dryland	Strongly Creeping	Excellent
Pioneer 524	Standard	Tap	Good
Drylander	Dryland	Strongly Creeping	Excellent
Algonquin	Standard	Modified Tap	Medium
Trumpetor	Flemish	Modified Tap	Fair
Beaver	Standard	Deeply Rooted Modified Tap	Medium
Rangelander	Dryland	Strongly Creeping	Excellent
Pacer	Flemish	Modified Tap	Fair
Heinrichs	Dryland	Moderately	Excellent

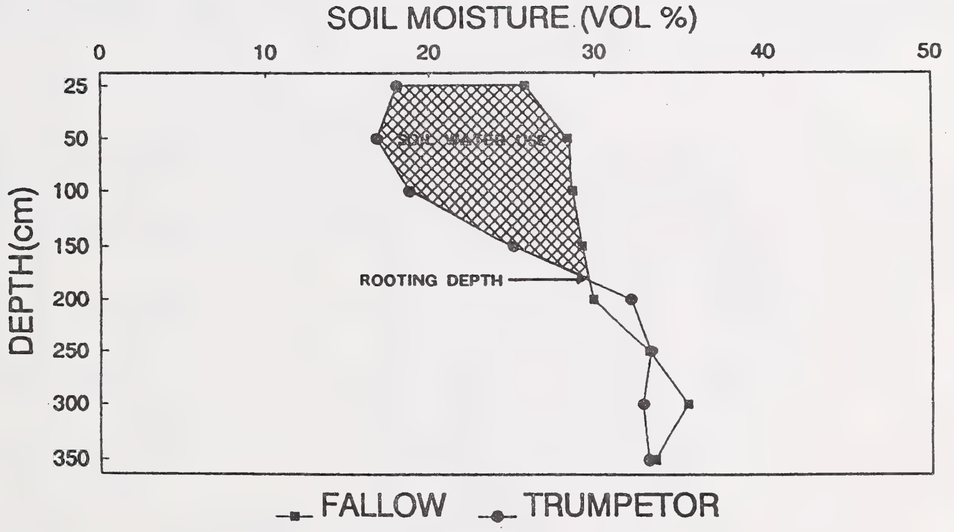

Figure 1. Example rooting depth and soil water use graph.

RESULTS

The performance of each alfalfa variety was ranked from one to ten (one being best) according to yield, rooting depth and soil water use. In addition, each variety was rated for

overall performance by totalling each individual ranking (Table 2). Evaluation of each alfalfa variety based on the three variables revealed Rambler to the best cultivar overall in the brown soils. Rambler ranked first in rooting depth and second in soil water use and yield.

It should be noted that the reported soil water use values may appear deceptively low for the yields produced. This is because they are based only on plant use from 25 cm to the calculated depth of rooting. In this case, groundwater is available for crop use. A significant portion of the water required by the alfalfa may come from this source. The quantity groundwater is difficult to determine. It was not the intent of this study to determine yield based on specific soil water use. Instead, the intent was to compare the performance of one alfalfa variety against another based on certain criteria. Since the entire plot area was subject to the same shallow groundwater, its influence will not be considered of consequence. Ideally, future studies of this nature would take place on land where the groundwater was deeper and not a concern.

Groundwater levels under the plot area remained relatively constant throughout each season. Significant fluctuations in water table depths appear to correspond to the occurrence, or lack of major rainfall events (Figure 2).

The mean, calculated rooting depth (1.5 m) was about 66% of the groundwater depth. This suggests that the alfalfa may be rooting into the saturated zone above the water table and penetrating no further. It is likely that deeper water tables may result in deeper rooting depths to a maximum depth of upward water transport by the plant.

CONCLUSION

Two seasons of study in the brown soils determined Rambler alfalfa to be the cultivar with the best overall combination of yield, rooting depth and soil water use. Studies in the dark brown soils have shown an entirely different ranking for the ten varieties studied. In that instance, Beaver alfalfa ranked number one overall.

It is likely that the environmental conditions associated with each particular soil zone affect the performance or suitability of the various alfalfa cultivars for that area. A certain variety which does well in one area may not perform as well in another. Planting of alfalfa is recommended on all dominant recharge areas as a control measure for dryland salinity. It is, therefore, important to evaluate the varieties on a zonal basis and develop recommendations in that regard. Plans to duplicate this study on a province-wide basis are being developed.

Table 2. Alfalfa yield, rooting depth and soil water use (average of 1992 and 1993) in the brown soil zone.

VARIETY	OVERAL L RANKING	YIELD Kg/ha	RANKIN G	ROOTIN G DEPTH (m)	RANKIN G	SOIL WATER USE (cm)	RANKIN G
Rambler	1	5165	2	1.70	1	6.8	2
Heinrichs	2	4997	4	1.59	3	6.9	1
Rangelander	3	4528	7	1.63	2	5.7	5
Beaver	4	5171	1	1.57	5	5.1	9
Pioneer	5	4592	6	1.57	4	5.7	6
Algonquin	6	4309	8	1.53	6	5.8	4
Drylander	7	5094	3	1.25	9	5.5	8
Pacer	8	4719	50	1.25	9	5.5	7
Spredor	9	4245	9	1.25	10	5.8	3
Trumpetor	10	3933	10	1.29	8	4.8	10

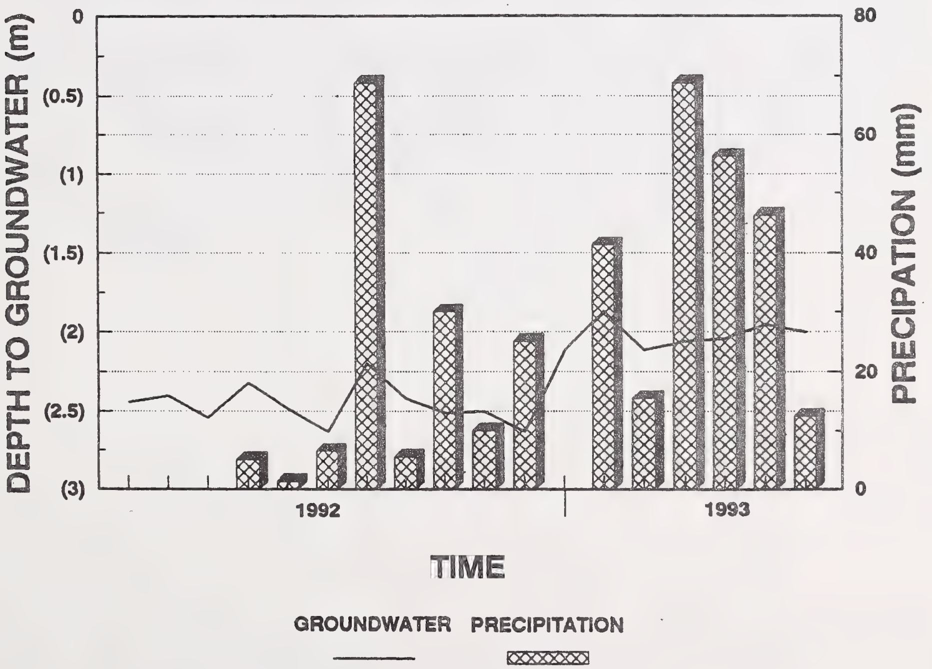

Figure 2. Groundwater movement and precipitation.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Mr. Alex Onody for providing the use of his land and in performing the farming operations necessary to conduct this project.

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A SOIL SALINITY INVENTORY OF THE PINE COULEE PROJECT

D. Wentz, B. Read and C. Livergood[39]

INTRODUCTION

A water diversion project has been proposed for Willow Creek, approximately 6km south-east of Stavely, Alberta. There is concern that the proposed on-stream storage in Pine Coulee may salinize adjacent land. The need arose to determine current soil salinity levels in the area. This information would serve as a benchmark against which any future salinity change could be measured. At the request of Alberta Public Works Supply and Services, the Conservation and Development Branch conducted a soil salinity inventory of the potentially affected area. This project also provided the C & D Branch the opportunity to refine their large scale soil mapping technology.

METHODS

Eighteen quarters (1165ha) of land were mapped in May, 1993 using automated EM38 techniques (Figure 1). This procedure involves the transport of an EM38 conductivity meter through the field, mounted on a PVC sled. The sled is pulled behind an all-terrain cycle along predetermined grid lines. In this instance, grid spacing was 50m (east-west). EM data was input into computer storage every 10m along each north-south line. About 200ha of land were mapped each day.

In each quarter, five test holes were drilled in 30 cm increments to a depth of 150cm. Soil was sampled and analyzed for EC, SAR, pH and cations. In addition, field soil moisture and texture were estimated.

Mean soil EC's were used to develop saturated paste equivalent predictive curves from EM38 readings using regression analysis. This information provided the basis for the production of salinity contour maps in EC units. A predictive curve and a salinity map were prepared for each quarter.

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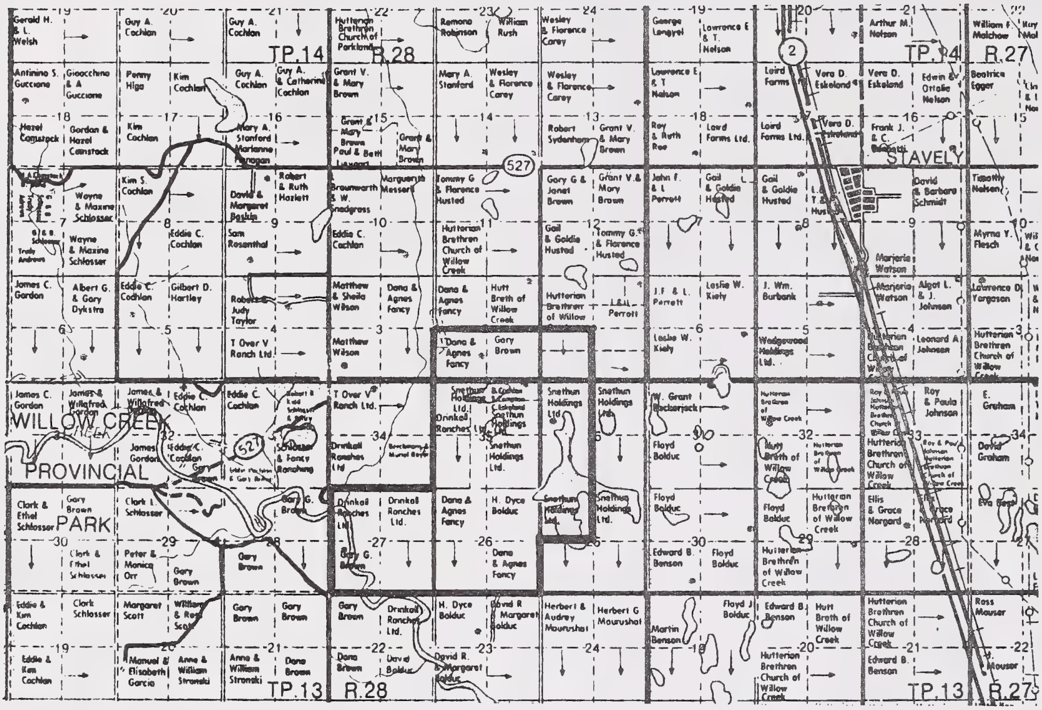

Figure 1. Area in which soil salinity survey took place (framed area).

RESULTS

Soil salinity levels were determined for each quarter section (Table 1). These values were arrived at by calculating a mean from all EM38 inputs recorded during mapping. Salinity ratings were assigned according to the following criteria:

EC <4.0 dSm = non-saline (ns)
EC 4.0 - 8.0 dSm = moderately saline (ms)
EC >8.0 dSm = strongly saline (ss)

Table 1. Soil salinity levels for each quarter section.

LAND LOCATION (W4)	MEAN EC (dSm)	SALINITY RATING
NW25-13-28	*	NS
NE26-13-28	1.33	NS
NW26-13-28	3.56	NS
SE26-13-28	0.67	NS
SW26-13-28	**	NS
NE27-13-28	*	NS
NW27-13-28	*	NS
SE27-13-28	*	NS
SW27-13-28	*	NS
NE35-13-28	1.70	NS
NW35-13-28	1.71	NS
SE35-13-28	0.69	NS
SW35-13-28	7.83	MS
NW36-13-28	1.71	NS
SW36-13-28	4.50	MS
SW01-14-28	0.88	NS
SE02-14-28	2.20	NS
SW02-14-28	0.38	NS

* salinity levels too low to develop a curve
** erroneous data

Based on the above, overall soil salinity in the study area at the time of mapping would be considered non-saline.

A saturated paste equivalent curve was prepared for each quarter (Figure 2). These predictive curves can be used in a field setting to approximate soil electrical conductivity. From the curve, a simple hand held EM38 reading can be converted to a saturated paste equivalent EC. Each curve is relevant for a specific quarter only. In some quarters, the range of salinity was too low to develop a curve. Use of the curves provides an inexpensive and labour saving method of monitoring salinity change over time.

Salinity contour maps in EC units were also prepared (Figure 3). These maps show the location and gradient of soil salinity within each quarter.

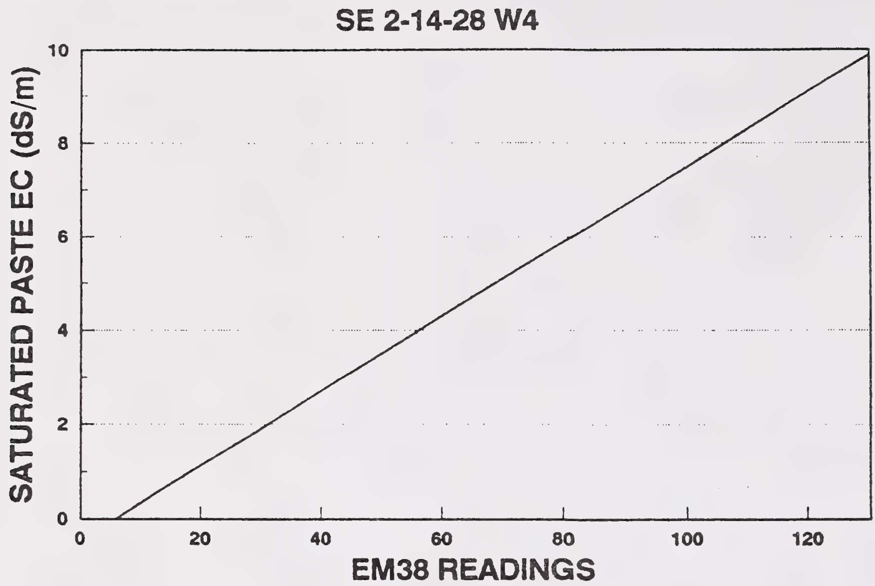

Figure 2. Saturated paste equivalent predictive curve.

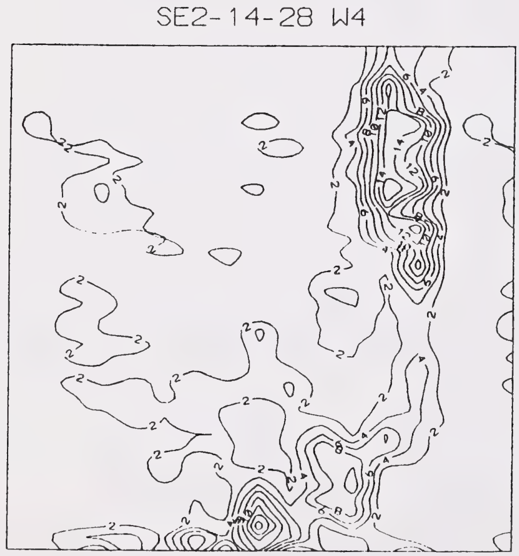

Figure 3. Salinity contour map in EC units.

CONCLUSION

EM38 mapping of the Pine Coulee study area has determined the region to be essentially non-saline. Salinity information on a specific quarter section basis is available.

Future changes in the soil salinity status which may occur due to on-stream water storage can now be noted. Furthermore, the ability to rapidly map large tracts of land in short periods of time has been demonstrated.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Mr. Neil McLean, Assistant Ag Fieldman, MD of Willow Creek for his assistance in performing the EM38 griding.

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CONSERVATION - WATER EROSION CONTROL

COMPARISON OF SOIL EROSION FROM NATURAL AND SIMULATED RAINFALL

S.C. Nolan[40], L.J.P. van Vliet[41] , T.W. Goddard[1] and T.K. Flesch[42]

INTRODUCTION

The relationship between field-scale natural erosion and erosion from single-nozzle rainfall simulators has not been well documented. The assumption when using a rainfall simulator is that the erosive energy of the simulator approximates natural rainstorms. However Tossel et al. (1990) found that the energy of simulated rainfall using the GRS II rainfall simulator is much lower than from natural rainfall. There is a need to determine the ability of portable rainfall simulators to reproduce the erosivity of natural rainstorms. The erosive energy of simulated and natural rainstorms can be simply compared using the erosivity or "R" factor of Wischmeier (1959) which represents the kinetic energy available for soil erosion in individual natural rainstorms. This field study compares simulated erosion generated by the GRS II (Tossel et al.1987) with erosion by natural rainstorms at similar rainfall erosivity values.

MATERIALS AND METHODS

This field study compared natural erosion with simulated erosion on an event basis. Plots (30 x 4.8 m) of conventional (CT), reduced (RT) and zero tillage (ZT) were established on a Solonetzic Gray Luvisol seeded to barley in the Peace River region. "Natural" soil loss was measured after five erosion events which occurred before crop establishment from 1987-91 as described in detail by van Vliet et al. (1993). "Simulated" soil loss was measured before crop establishment in 1991, using a GRS II portable single-nozzle rainfall simulator (Tossell et al. 1987) with 1 m^2 soil coverage at intensities of 60 and 140 mm h^{-1}. Table 1 lists the soil surface conditions present at the time of the rainfall simulations. Cumulative simulated soil loss was calculated from subsamples obtained during the simulation as described by Nolan et al. (1994). Simulated soil loss equivalent to each natural soil loss event was calculated for different simulation durations representing the erosivity (energy times intensity) of each of the five natural rainstorms.

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Table 1. Soil surface conditions before spring tillage (1991) on simulated rainfall plots

Tillage Type	Crop Residue Cover (%)	Roughness Index[z]	Soil Moisture (%)	Bulk Density (g cm^{-3})
Conventional	48 b[y]	126 b	11.7 a	1.1 a
Reduced	53 b	335 a	11.8 a	1.1 a
Zero	89 a	195 ab	9.0 a	1.1 a
Standard Error	2.5	46	2.5	0.1

[z] Rillmeter method, index after Romkens and Wang (1986).

[y] Values within a column followed by the same letter are not significantly different at P = 0.05 using Fisher's protected LSD.

RESULTS AND DISCUSSION

The R values of the natural erosion events are illustrated in Fig. 1a) and the corresponding soil loss from each treatment in Fig. 1b). These five natural events caused over half of the four-year total soil loss from CT (van Vliet et al. 1993) which occurred prior to crop establishment. The tillage treatments represent three different conditions for which natural and simulated erosion were compared. The natural soil loss order was CT > RT > ZT, although CT was not significantly different (P=0.05) from RT for four of the five events. The CT and RT treatments exhibited similar soil loss only because of the timing of our study, when both were observed to be in similar states of soil tilth and crop residue cover after the winter period. Soil loss from CT was significantly greater than from ZT for all of the five events (P = 0.10).

For the simulated erosion, cumulative soil loss curves and the R values corresponding to the time since simulation began are illustrated for the low and high intensity simulations (Fig. 2). Each soil loss curve shows an initial period of total infiltration, until runoff started. Runoff was earliest for CT and RT and latest for ZT. The ranking of simulated soil loss generally corresponded with that of the natural, where CT > RT > ZT. Differences in soil loss from CT and RT were not significant, as with the natural soil loss.

Total soil loss from all five natural events were compared with total soil loss from the five corresponding simulated events. The rainfall simulator preserved the order CT > RT > NT, but showed large differences between the results of the two intensities (Table 2). The best agreement between natural and simulated soil loss was found for the high intensity simulation where, as a percentage of natural, the simulated was 72 % for CT, 72 % for RT (no significant difference from natural), and 4 % for ZT. The lower simulated soil loss from ZT was likely influenced by the almost complete soil surface cover; which would reduce the

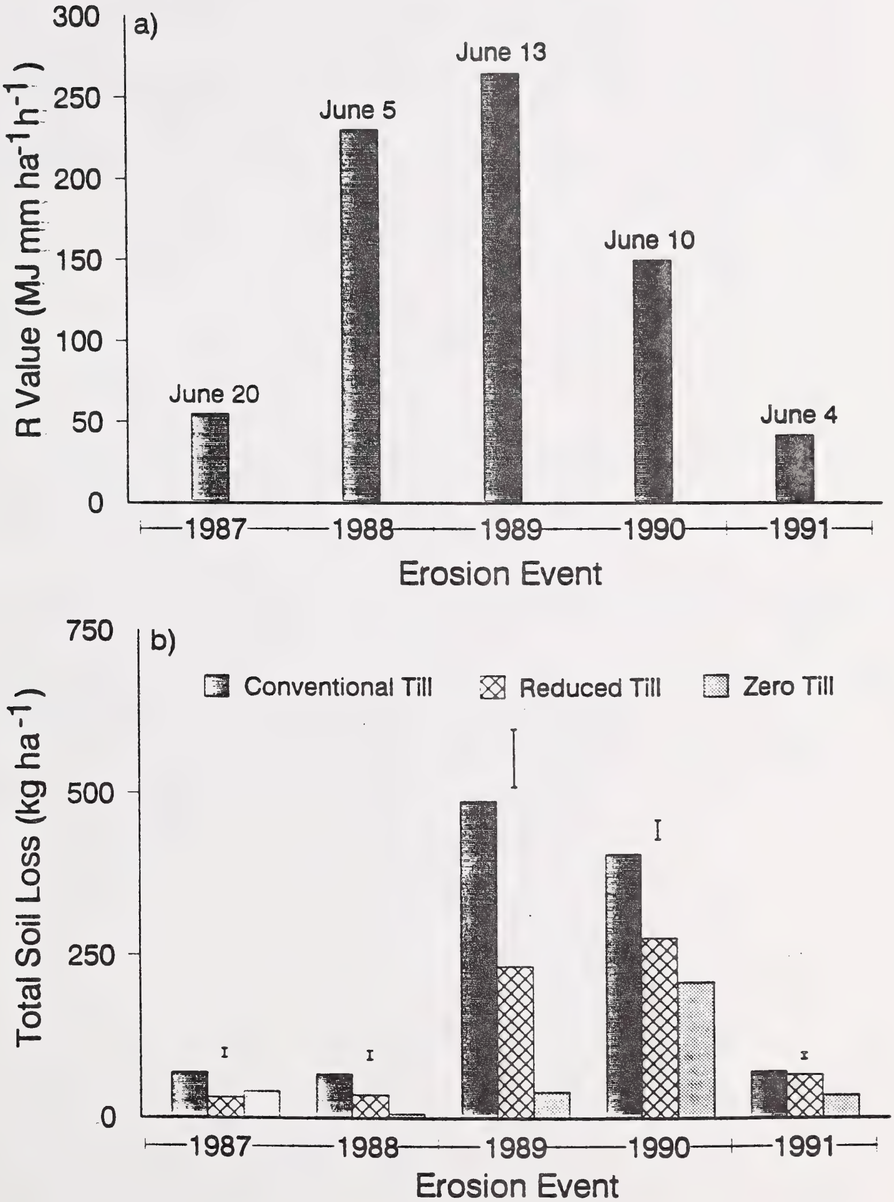

Figure 1. Rainfall erosivity (R) values (a) and resulting soil loss (b) from natural rainfall plots for five erosion events (1987 to 1991). Bars represent standard error.

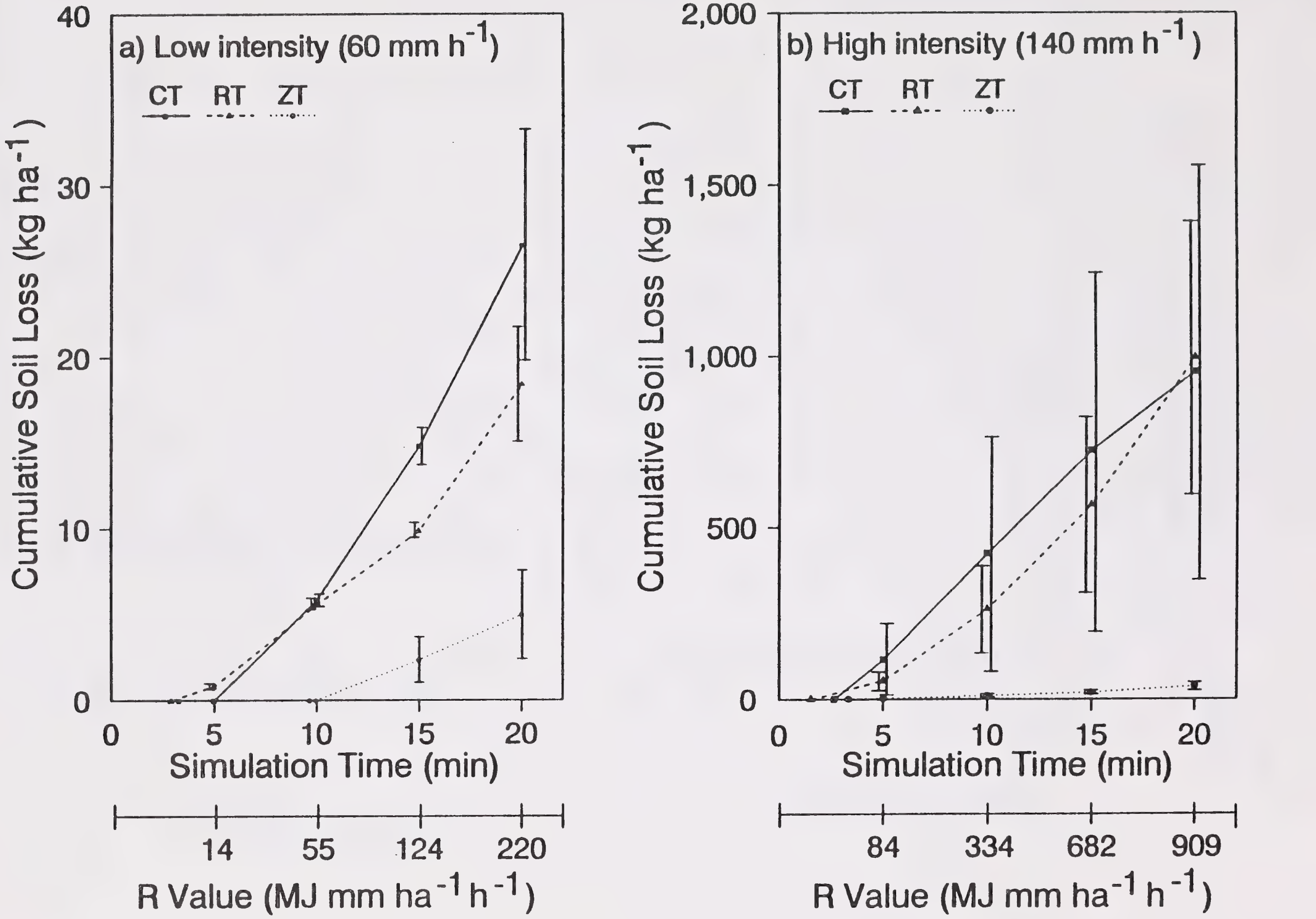

Figure 2. Cumulative soil loss during rainfall simulations for conventional till (CT), reduced till (RT) and zero till (ZT) treatments at low (60 mm h^{-1}) and high (140 mm h^{-1}) intensities. Bars represent pooled standard error, to right for CT, to left for RT and centre for ZT.

Table 2. Comparison of natural and simulated erosion prior to crop establishment for conventional till (CT), reduced till (RT) and zero till (ZT) treatments

	Soil Loss (kg ha^{-1})		
	CT	RT	ZT
a) Sum Total of Five Erosion Events (Cumulative R = 724.1)			
Natural	1102.5 a[z]	643.6 a	331.7 a
	(1.00)	(0.58)[y]	(0.30)
Simulated:			
High	798.5 a	462.3 a	14.5 b
	(1.00)	(0.57)	(0.02)
Low	69.2 a	64.0 b	15.6 b
	(1.00)	(0.93)	(0.23)

[z] Values with a column followed by the same letter are not significantly different at P = 0.05 using Fischer's LSD. Capital letters denote separate test set.

[y] Ratio of soil loss with respect to conventional treatment.

importance of the rainfall energy used as the basis for matching simulated and natural soil loss.

The low intensity simulations resulted in a ranking of CT > RT > ZT, but the magnitude of soil loss was greatly underestimated compared with natural erosion. Simulated soil loss as a percentage of natural was only 6 % for CT, 10 % for RT, and 5 % for ZT. However, when values are reported as a relative ratio of soil loss from CT (Table 2), the simulated soil loss ratios were within 35 % of the natural ratios for RT and ZT. This low intensity (60 mm h^{-1}) is close to that which is commonly used for studies of simulated erosion (Elliot et al. 1992; McIssac and Mitchell 1992; West et al. 1991).

Matching R values directly for the high intensity simulation gave good agreement for CT and RT, where the soil surface is exposed. Our results also show that if one is interested only in relative erosion amounts, then lower simulation intensities can be used. For conditions when the soil surface is covered with crop residue (ZT), it appears that more work is needed to accurately match rainstorm intensity and volume.

This study shows that a wealth of information is available from rainfall simulator data when subsamples are taken throughout the simulation to establish cumulative erosion rates for simulation times which can then be related to specific natural erosion events. Cumulative simulated soil loss can then be related to the natural climatology of an area, allowing a user to approximate erosion from any natural rainfall event occurring during soil and crop conditions similar to those present at the time of the rainfall simulation.

CONCLUSIONS

When soil loss generated with a GRS II rainfall simulator was compared with soil loss from natural rainfall for five erosion events, the rainfall simulations preserved the natural soil loss order of CT > RT > ZT. Best agreement was found using a 140 mm h^{-1} simulation intensity, where total soil loss from both conventional tillage and reduced tillage was not significantly different from the natural soil loss (within 72 %). Poor agreement was found for zero tillage, where simulated soil loss was significantly less than the natural soil loss (4%). This was likely influenced by the almost complete soil surface cover on the zero tillage, reducing the importance of the erosive energy of the rainfall, which was used as the basis for matching natural and simulated soil loss. For the 60 mm h^{-1} intensity simulations, only the relative magnitudes of soil loss appeared to be usefully related to natural soil loss, as the absolute soil loss values were poorly reproduced by the simulator.

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TESTING WEPP AND EPIC ON HILLSLOPES USING ALBERTA EROSION DATA

Andrzej Jedrych[43], Sheilah Nolan[1], Douwe Vanderwel[1], Tom Goddard[1]

INTRODUCTION

Water erosion is an important degradation process affecting land productivity in Alberta. Water erosion effects on crop productivity are hardly detectable during early stages but may become drastic once erosion signs are evident. Corrective measures to either reduce water erosion or repair damage usually requires greater degree of planning, capital, and labour. Water erosion may be reduced with conservation techniques but not eliminated. The key objective of conservation planning is, therefore, to select agricultural practices that minimize soil erosion and meet economic and social needs. Towards this end there has been continuous effort in developing tools that predict the outcome of complex interactions governing soil erosion and productivity. Soil erosion models are a cost effective means of extrapolating site data to other areas for the assessment of erosion in different scenarios. However, most soil erosion models were developed in conditions which are different than those present in Alberta. There is a need to verify the adaptability of soil erosion models to Alberta conditions. The objective of year 1 of this study was to concurrently test, using common datasets assembled from published erosion studies in Alberta, the ability of EPIC and WEPP to predict water erosion and runoff from hillslopes.

MATERIALS AND METHODS

Model Descriptions

The WEPP and EPIC models were chosen for initial evaluation as EPIC represents an interacting model of updated USLE technology and crop productivity and WEPP represents the newest technology in soil erosion modelling. We used EPIC version 3090 and selected the Modified USLE (MUSLE, Williams 1975) to estimate erosion. EPIC provides daily integrated annual soil erosion estimates. WEPP version 91.5 (D. Flanagan, USDA-ARS, 1993, provides estimates for single storms or for a continuous simulations (annual sum of erosion events). To evaluate the two models, the annual result of the continuous simulation mode of WEPP was used. The exception is one data set (Beke et al. 1990) which was not suited for use in an annual context and was evaluated using only the WEPP model in the single storm mode.

Data Sources

Chanasyk and Woytowich (1984): The objective of this study was to define potential and actual surface drainage and erosion problems in the Peace River region. Snowmelt and rainfall runoff were measured from four 75 m x 5 m plots located on a 5% slope with a

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westerly aspect at La Glace near Grande Prairie. The longer than standard Wischmeier plot length was used to reflect the longer slopes that characterize the Peace River region. The plot treatments were fescue, and canola-barley-fallow rotation.

Saturated hydraulic conductivity (Ksat) was measured, but not at the time of runoff measurements. Critical values for crop management information were missing although the local District Agriculturalist and weather records were consulted to determine likely tillage and seeding dates. For WEPP, values of interill, rill, and critical shear were not available.

Beke et al. (1989, 1990): Sediment and runoff studies were conducted on dark brown chernozemic soils near Lethbridge in the summers of 1986 and 1987. The objective was to measure and evaluate the characteristics of sediment and runoff water as influenced by cropping and tillage practices. A single side roll irrigation sprinkler was used to simulate rainfall. Water was applied for a number of durations and intensities, chosen to represent probable rainfall rates from summer storms in the area. Replicated plot treatments were bare fallow, perennial alfalfa, barley, and barley seeded along the contour. The plots were located on a 4% slope.

Data from this study provided the most complete set of information on saturated hydraulic conductivity. Values for interill, rill, and hydraulic shear however were not available. As well, lack of crop canopy data made the estimation of values necessary. Data from this study were used in the single storm simulation mode of WEPP. The data were not suited for use with the EPIC model.

Model Initialization, and Runs

Chanaysk and Woytowich (1984): The 1981 - 1983 Beaverlodge CDA daily climate data was used in the continuous mode simulation when study data were not available. The daily total precipitation in the climate file included measured precipitation data from the La Glace site for the May - October period of 1982 and 1983 (Figure 11b and 11c, Chanaysk and Woytowich, 1984). The soil series at La Glace is an Albright clay loam Solonetzic soil developed on glacio-lacustrine parent material on long, gentle slopes. It was assumed that the oat field was cultivated twice in the spring and the fallow field was cultivated three times during the growing season. One harvest was assumed for the fescue treatment with no tillage. For the WEPP simulations, interrill and rill detachment parameters and critical shear were estimated from charts of values for USA soils (Flanagan, 1991), based on soil texture.

Beke et al. (1989, 1990): The WEPP model simulations were conducted in the single storm mode, using the 1986 data, which included intensities of 12, 20 and 31 mm h^{-1}. Nine durations of rainfall ranging from 30 to 120 minutes in various combination were used with the three different applied rainfall intensities. No other climate data were used in this simulation.

The soil series was a Lethbridge sandy clay loam (Dark Brown Chernozem) developed on glaciolacustrine parent material. Detailed soils information was available at the time of the rainfall simulations, including Ksat, bulk density and texture. Erosion

detachment parameters and baseline critical shear were estimated from similar USA soils (Flanagan, 1991) based on soil texture. The fallow field was cultivated once with a blade in the middle of the summer to a depth of 0.06 m. It was assumed that there was zero canopy and residue cover during the rainfall simulations.

RESULTS

Chanaysk and Woytowich (1984)

The WEPP and EPIC simulations of runoff and sediment yields for 1982 and 1983 at La Glace were compared with the observed runoff and sediment yields from the fallow, barley, and fescue treatments. Results were compared for spring and summer separately (Table 1) since improvements to the winter routines of WEPP are being developed.

The EPIC model showed closer agreement with the observed spring runoff data than did WEPP (Table 1). The WEPP model simulated summer runoff events more closely and with less variability than EPIC. Both models underestimated runoff volumes. Both models did not predict any runoff in 1981, a season of low measured runoff. Predicted annual soil loss by WEPP was within one order of magnitude. The treatment ranking of fallow > barley > fescue was consistent between observed and simulated results from both models.

Beke et al. (1989, 1990)

Comparisons of model predictions with observed results was possible for the fallow treatment only, due to lack of data on crop canopy cover for the other treatments. The single-storm simulation for the fallow treatments indicates closer agreement between observed and predicted runoff volume than between observed and predicted soil loss (Table 2). The initial results indicate that WEPP underestimated runoff yield for the lower intensity rainfall by a factor of less than two, and overestimated runoff yield for the higher intensity by a factor of five. For the lower intensity rainfall, soil loss was overestimated by a factor of five; for the higher intensity, by a factor of ten. In general, all values predicted by WEPP were within an order of magnitude of the observed values.

The repeated data allowed assessment of the model based on the variability of the observed data. The 95 % confidence intervals surrounding the observed mean erosion values are illustrated in Table 2. Thirty three percent of both runoff and soil loss predicted by WEPP was within these intervals. Results were closest for the lower intensities. It should be noted that some of the observed erosion data appeared to be inconsistent with what would be expected. For example, observed runoff at 12 mm h^{-1} after a 120 min duration was unexpectedly greater than runoff at 31 mm h^{-1} after a 120 min duration (Table 2). The WEPP results however did reflect expected trends, as runoff for the higher intensity simulation was predicted to be greater than that for the low intensity simulation at the same duration.

Table 1: Comparison of observed runoff and sediment yields from EPIC and WEPP simulations at la Glace, Alberta (1981-1983)

Treatment	Runoff (mm)					Soil Loss (kg/ha)				
	Observed	EPIC	RMSE[1]	WEPP	RMSE	Observed	EPIC	RMSE	WEPP	RMSE
1982 Springmelt										
Fallow	91.5	39.5	10.4	51.4	5.8	2027	1923	374.3	0	350.9
Canola	-	34.2	-	6.0	-	-	538	-	0	-
Barley/Oats	81.3	30.4	11.8	6.0	10.4	390	161	70.1	0	70.0
Fescue/Grass	74.4	24.6	11.0	4.8	9.8	260	9	39.8	0	39.8
1982 Summer Rains										
Fallow	-	39.7	-	39.7	-	23	1160	256.2	266	47.9
Canola	-	23.3	-	29.9	-	37	1509	411.6	261	61.5
Barley/Oats	-	17.4	-	31.1	-	18	312	77.6	402	96.5
Fescue/Grass	-	5.4	-	35.0	-	18	9	4.7	34	77.6
1982 Annual										
Fallow	-	-	-	-	-	2050	3083	334.9	266	279.0
Canola	-	-	-	-	-	-	2047	-	261	-
Barley/Oats	-	-	-	-	-	408	473	73.0	402	81.0
Fescue/Grass	-	-	-	-	-	278	18	31.6	34	31.5
1983 Springmelt										
Fallow	50.3	11.4	8.4	0.0	9.3	245	58	44.4	0	47.6
Canola	49.8	10.4	7.5	2.1	8.3	79	94	14.6	0	15.1
Barley/Oats	45.4	9.3	8.0	0.0	8.1	85	28	18.4	0	17.1
Fescue/Grass	46.8	4.7	8.3	0.0	8.2	55	1	11.7	0	11.7
1983 Summer Rains										
Fallow	-	43.1	-	36.1	-	2	854	136.1	266	41.6
Canola	-	26.8	-	35.8	-	19	1457	190.3	635	111.9
Barley/Oats	-	28.9	-	44.2	-	11	1924	367.0	1198	192.2
Fescue/Grass	-	7.3	-	24.6	-	2	15	3.1	46	9.0
1983 Annual										
Fallow	-	-	-	-	-	247	912	109.3	266	44.0
Canola	-	-	-	-	-	98	1551	149.1	635	87.9
Barley/Oats	-	-	-	-	-	96	1952	287.1	1198	150.7
Fescue/Grass	-	-	-	-	-	57	16	7.7	46	10.2

[1] Root Mean Square Error

Table 2: Comparison of single storm WEPP prediction with observed runoff and soil loss from fallow treatment in Lethbridge area (1986)

Simulated Rainfall		Runoff Yield (mm)				Soil Loss (t/ha)			
Intensity (mm)	Duration (min)	Observed	LCI*	UCI*	Predicted	Observed	LCI	UCI	Predicted
12	30	0.87	-0.79	2.53	0.00	0.02	-0.02	0.06	0.00
(+/- 2.5)	60	2.20	0.38	1.02	1.65	0.17	-0.31	0.65	0.28
	90	5.77	5.04	6.50	4.84	0.16	-0.69	0.38	0.49
	120	9.61	8.28	10.94	8.38	0.25	-0.49	0.78	0.70
	RMSE **				0.93				0.29
20	30	2.78	1.03	4.53	2.42	0.11	-0.08	0.30	0.50
(+/- 2.0)	45	3.45	2.64	4.26	5.64	0.17	-0.04	0.38	0.90
	RMSE				1.57				0.59
31	30	2.42	1.86	2.98	7.70	0.16	0.12	1.21	1.72
(+/- 2.0)	60	4.88	4.06	5.70	19.91	0.21	-0.03	0.44	3.93
	120	7.94	7.24	8.64	45.81	0.60	-0.02	1.23	8.59
	RMSE				23.72				5.17
	Total RMSE				13.73				3.00

* Lower confidence interval (LCI) and upper confidence interval (UCI) at P=0.05
** Root Mean Square Error
Note: Initial interrill, rill, and canopy cover assumed to be zero percent

SUMMARY

From this limited initial evaluation, it appears that both WEPP and EPIC show good potential for predicting soil erosion in Alberta. However, problems of data availability may be limiting for WEPP. Further testing of both models and their estimated input parameters is required. If WEPP can predict Alberta erosion, it appears to be suited for use in an experimental or research applications. WEPP is a complex and detailed model, but it also appears to have long-term potential for more applied uses. If EPIC can predict Alberta erosion, its advantages include: its ease of use, the required data are more readily available, and the output can be usefully integrated with crop production information (not evaluated here).

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EFFECT OF GRAZING ON INFILTRATION RATES ON A PEACE RIVER NATIVE GRASSLAND

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ABSTRACT

A rainfall simulator was used in a preliminary study to examine the influence of livestock grazing on infiltration capacity of native grasslands found in the Peace River valley. The study compared infiltration and runoff rates from a long term, heavily grazed grassland and an adjacent ungrazed grassland. The simulations were conducted at an intensity of 140 mm h^{-1}, standardized to 22 minutes. The heavily grazed, fair condition range had 38% exposed soil compared to no exposed soil on the excellent condition ungrazed range. The fair condition range produced 38% less green plant matter and had 95% less litter cover than the excellent condition range. Soil loss and total runoff were collected and infiltration was calculated by difference between the amount of water applied and total amount of runoff collected. The average total cumulative runoff was 3.1 times greater and soil loss was 4.4 times greater on the grazed site than on the ungrazed site. The final infiltration rate of the heavily grazed plots was about one half that of the final infiltration rate from the ungrazed plots. The limited vegetative yield and litter mass on the heavily grazed area had a significant effect on infiltration potential. This study suggests that heavy grazing and the resulting reduction in vegetation production have caused a significant decrease in infiltration capacity of this native grassland along the Peace River.

INTRODUCTION

Infiltration capacity of grasslands is important for their maintenance and sustained productivity. The steep terrain along the Peace River make these grasslands extremely susceptible to reduced infiltration and the resulting erosion damage from increased runoff volumes.

Grazing activities (intensity, season of use and reduction in range condition) have been identified as having an impact on infiltration rates in a number of studies (Johnston 1962, Gifford and Hawkins 1978, Blackburn 1984, Naeth et al. 1990 b). The removal of plant matter (both living and dead) and changes to soil structure significantly reduce the soils ability to absorb and retain moisture (Meeuwig 1970, Irving 1992).

A 1975 investigation of public land grazing leases on the Peace River slopes found that it is common practice to graze cattle from early spring to fall in a continuous grazing system (Richardson 1976). Present observations indicate that this is generally still the case. These practices are similar to those which showed the greatest reduction in infiltration capacity on other Alberta rangelands (Naeth et al. 1990b, Johnston 1962).

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Observations of sheet and gully erosion on grazed native range along the slopes of the Peace River prompted the investigation into the effects of livestock grazing on infiltration and runoff. The objective of this study was to investigate the influence of grazing intensity on infiltration, to demonstrate different runoff rates between an ungrazed and grazed site using the GRS II rainfall simulator, and to assess the use of the rainfall simulator to measure soil loss and infiltration on rangelands.

MATERIALS and METHODS

Site Description

The grasslands of the Peace River valley are found on a diverse landscape of rolling and steep slopes (0-70%) that have developed through slumping. Soil development reflects the diversity resulting from the landform and vegetation, and is a mix of Chernozemic, Brunisolic and Regosolic soils.

The specific site chosen for this study was located approximately 50 km southwest of Peace River, Alberta. It was located on the boundary between two grazing associations where a double fenceline exists. The fences created a 7m laneway where native grasslands have been allowed to remain ungrazed for approximately 30 years (Watchorn, personal communication 1993). A comparable site that has been heavily grazed for approximately 30 years lies directly across the fence. This site is part of a lease that has been in effect since 1901 and has been used under long term continuous grazing practices common on the Peace River slopes.

Infiltration Tests

A rainfall simulator (Tossell et al., 1987) was used to imitate rainfall activity. The simulator is a tripod with a single, solid cone sprayer nozzle and a pressure gauge, which when hooked up to a water and power source can deliver water under pressure at varying intensities.

Trials were conducted on July 27 and 28, 1993. The simulator was set up over a 1 m^2 bounded plot within the study area and a constant rate of water was applied at a target intensity of 140 mm h^{-1} (5.5 in. h^{-1}). Three repetitions were done on both the ungrazed and the adjacent heavily grazed area. All runoff (water and soil) from each plot was collected to determine total cumulative runoff and soil loss. Soil loss and runoff rates were determined by collecting runoff subsamples every three minutes for up to 1 minute in duration.

Infiltration rate was calculated by difference between runoff rate and actual applied rates of water. Data was standardized to a 22 minute end time for comparison. An analysis of variance (ANOVA) was used with the Student Newman Keuls test at a significance level of 0.05 to test for difference between the treatments.

A core, 6 cm deep, was removed from the surface (Ah) soil outside the frame of each plot prior to the simulated rainfall. Bulk density and soil moisture content were determined gravimetrically. Bulk samples of the same horizon were taken to determine soil organic matter content (using total carbon combustion) and soil texture (using hydrometer method).

The slope within each square meter plot was measured with an Abney level. Plot sites within each treatment were selected on the basis of similar amount of ground cover, plant species composition and slope.

Vegetation Sampling and Analysis

Prior to the simulated rainfall treatment, vascular plant species were identified within each plot using Moss (1983) as the botanical reference. Percent cover for individual species, litter, exposed soil, moss and lichen was visually estimated and species were given a Daubenmire cover class (Daubenmire 1959). Range condition was estimated using average cover class value, percent exposed soil, percent litter cover, plant vigour and productivity as judgement criteria (Adams 1981).

Following the simulated rainfall treatment, two - 1/10 m^2 plots within each 1 m^2 plot were hand raked to collect the litter (dead plant material). Living plant material was sheared to ground level, separated and collected as grasses or forbs. Collected materials were air dried and then weighed. Calculations were made to convert them to units of kilograms per hectare.

Statistical comparison of the plant matter yield data was conducted using a T-test incorporating a test for equality of variance. Vegetation cover measurements were not subjected to statistical analysis.

RESULTS

The soil on the grazed site was classified as an Orthic Eutric Brunisol while the ungrazed site was classified as a Rego Black Chernozem. Table 2 outlines the soil properties that were measured at the study site. Soil texture on both sites was silty clay. There were no statistically significant differences in soil property values between heavily grazed and ungrazed treatments.

Table 2. Surface Soil Properties of Rangeland Infiltration Test Sites.

Run ID	Treat-ment	Soil Moisture	Bulk Density (Mg/m^3)	Sand %	Silt %	Clay %	Organic Matter %
1051	Grazed	29.62	0.88	5.0	40.0	55.0	12.5
1053	Grazed	17.91	1.01	20.0	32.5	47.5	13.7
1054	Grazed	14.54	1.24	12.0	35.0	53.0	13.1
Mean		20.69	1.04	12.3	35.8	51.8	13.1
SD		7.92	0.18	7.5	3.8	3.9	0.6
1061	Ungrazed	25.91	1.06	20.0	34.0	46.0	15.7
1063	Ungrazed	27.13	0.85	19.0	28.0	53.0	13.4
1064	Ungrazed	37.29	0.67	24.0	40.5	35.5	22.5
Mean		30.11	0.86	21.0	34.2	44.8	17.2
SD		6.25	0.20	2.6	6.2	8.8	4.7

The trials were conducted shortly after the peak of the growing season for most plants on this range type. Production of grasses, forbs and litter from both the grazed and ungrazed sites is presented in Table 3.

The ungrazed plots were dominated by Upland Sedge - Western Wheat Grass - Prairie Crocus - Western Porcupine Grass. There was no exposed soil in the ungrazed plots. Plant vigour was considered good, judged by plant height and leaf blade development on key species. Range condition was determined to be excellent based on species composition, high plant productivity, large quantities of litter and the absence of exposed soil (Adams 1981).

The grazed sites were available for grazing up to the time of the study and use by cattle appeared light. Livestock removed an unknown portion of the 1993 production prior

to the rainfall simulation. Dominant plants on the grazed site were Upland Sedge - June Grass - Dandelion - Pasture Sagewort. There was an average of 38% exposed soil on grazed plots. Plant vigour was considered poor based on reduced plant height and leaf development of key species compared to the same species in the ungrazed plots. The fair condition assessment of the grazed plot was based on species composition, reduced litter cover, extent of exposed soil and reduced plant vigour (Adams 1981).

Table 3 compares average plant matter yields on the two treatments. Litter yield was significantly greater on the ungrazed than the grazed treatment.

Table 3. Average Plant Matter Yield for Grazed and Ungrazed Sites - kg/ha (lbs/ac)

	GRAZED	UNGRAZED
Grasses	747.1 (665.0)	2461.0 (2190.3)**
Forbs	845.5 (752.5)	93.4 (83.1)*
Litter	228.5 (203.4)	4788.2 (4261.5)*
Total Herbage	1592.7 (1417.5)	2554.3 (2273.4)

** yield between sites are significantly different at $P \leq 0.01$
* yield between sites are significantly different at $P \leq 0.05$

Visual best fits were used to determine average final infiltration. Figure 1 illustrates the infiltration curves for each plot. Infiltration rates on the grazed site showed a steep decline from an initial 114 mm h^{-1} for the first 6 minutes and then levelled off at 45 mm h^{-1}. The infiltration on the ungrazed plots showed a steep decline from 116 mm h^{-1} for the first 4 minutes and levelled off at 90 mm h^{-1}. Infiltration rates were two times greater on the ungrazed site.

Figure 2 shows the mean total runoff and soil loss from the grazed and ungrazed sites. Total runoff and soil loss were statistically significantly different between treatments at $p=0.05$. These results show 3.1 times the total cumulative runoff and 4.4 times more soil loss from the grazed site compared to the ungrazed. The slopes of the ungrazed and heavily grazed plots were both 11%.

DISCUSSION

The plant species composition on the grazed compared to the ungrazed treatment showed a trend consistent with observations made by Adams (1981) on similar sites exposed to long term, heavy grazing practices. Changes with grazing include reduced cover and frequency of decreaser species, greater cover and frequency of increaser and invader species, an increase in exposed soil and a decrease in litter cover. Changes in species composition was evident as the grazed treatment showed a trend away from the tall grass species of Western Wheat Grass and Western Porcupine Grass toward the mid grass species such as June Grass and a greater forb component.

The season long continuous grazing system that has been in effect on this grassland for

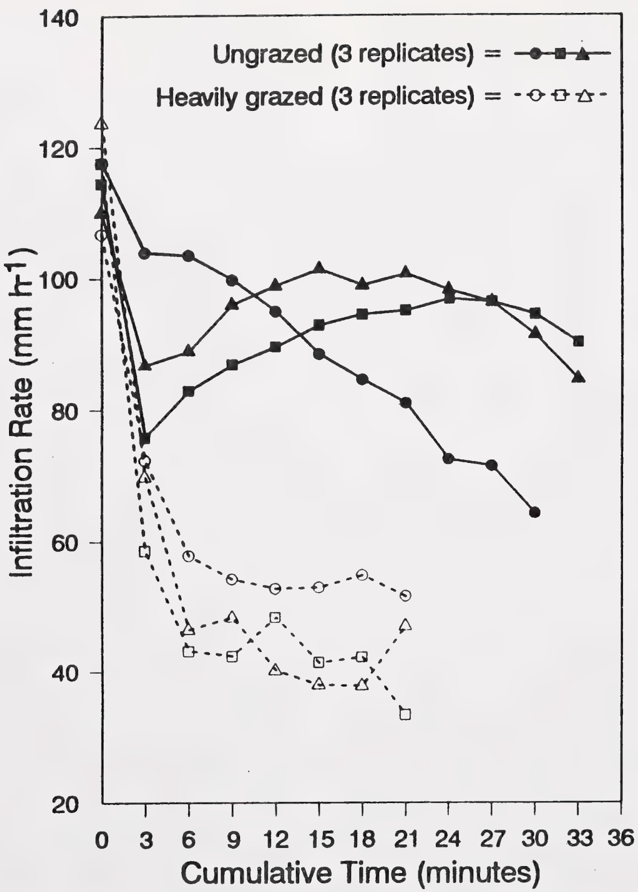

Figure 1: Infiltration rate curves for heavily grazed and ungrazed treatments on a native grassland in the Peace River valley.

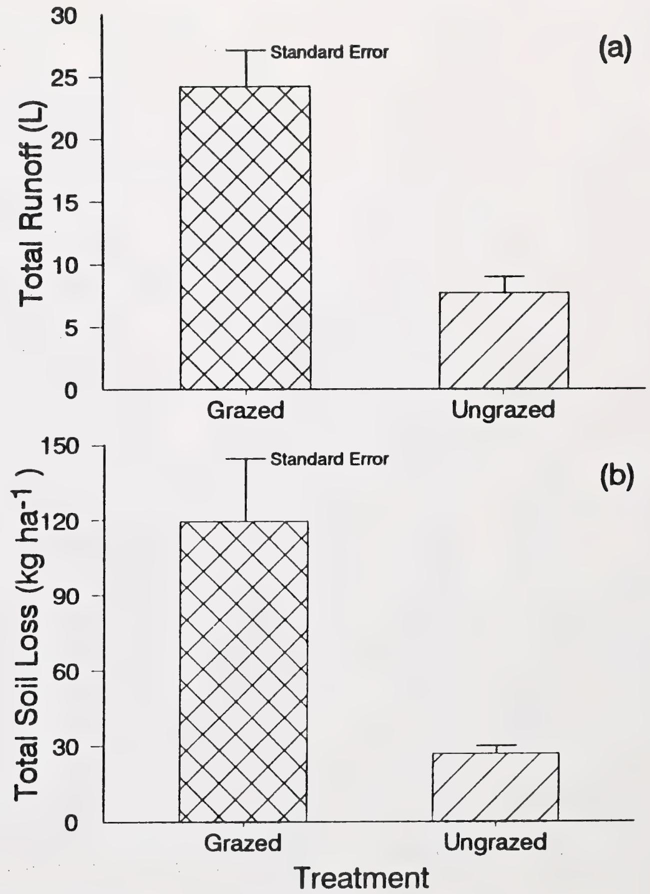

Figure 2: Total cumulative runoff and soil loss from a native grassland in the Peace River valley after 22 minutes of simulated rainfall on heavily grazed and ungrazed treatments.

at least the past 30 years does not appear to have altered soil properties in the study plots (Table 2). There was no statistically significant difference in bulk density or percent organic matter between the grazed and ungrazed treatments.

The final infiltration rate was two times greater for the ungrazed treatment and total cumulative runoff was 3.1 times greater for the grazed treatment. The infiltration differences could not be related to the measured soil properties (Table 2). This suggests that the measured vegetation factors were the sole influence for runoff and infiltration differences between grazed and ungrazed plots. Infiltration on grazed plots did not increase after the initial decline possibly due to the lack of ground cover. Meeuwig (1970) found plant and litter cover to be the most important variable measured to influence infiltration. Surface sealing on areas of exposed soil may have further reduced infiltration (Browning 1973).

There was 4.4 times more soil lost from the grazed treatment than from the ungrazed treatment. The most important factor in reducing runoff and increasing infiltration is above ground plant matter yields (Meeuwig 1970, Naeth et al. 1990b). Plant cover reduces raindrop impact on the soil surface (Browning 1973) preventing soil dislodgement, surface sealing and increased runoff. Increased soil loss from the grazed treatment appears to be influenced by reduced plant cover and plant yield.

Application of the GRS II Rainfall Simulator

The modified GRS II rainfall simulator performed well on native rangeland. The microplot borders could be hammered into the surface adequately. Some pre-cutting with a knife was needed for the sod of the ungrazed treatments. No leakage was observed on any borders.

Since the simulator has larger water supply needs than other infiltrometers, rangeland sites must be accessible by trucks. Water consumption can be 200 L per microplot (approximately 400 L hr^{-1}).

The GRS II is more suitable than an apparatus such as the double ring infiltrometer due to the slope of the site and the variability of small areas (GRS II measures a much larger area and as such is not unduly influenced by cracks, plant crowns, etc).

Management Implications

Grazing management practices that promote or improve litter cover and maintain plant species typically found on good condition range will benefit infiltration and in turn production. Heavy grazing can reduce plant health and create a change in species composition on rangeland. A change in species can result in decreased plant matter yields and litter accumulations. As litter cover decreases soil exposure may increase allowing for greater soil surface evaporation and soil erosion. If stocking rates are not adjusted as plant production decreases there is less plant matter left to benefit infiltration and protect the soil surface and range condition will continue to deteriorate. Good grazing management should maintain or improve range productivity and limit soil and moisture loss.

CONCLUSIONS

Plant matter yield (both litter and live green) on a heavily grazed grassland was 1/4 that of the ungrazed control. The above ground vegetation production and litter influenced infiltration such that the infiltration rate on the heavily grazed area was 1/2 that of the ungrazed control. Long term, continuous heavy grazing, lower amounts of plant matter and the resulting

decreased infiltration limits the water availability to plants. This leads to less productive species present in the grazing area.

Infiltration was significantly lower, and runoff significantly higher, on the heavy grazed rangeland than on the ungrazed rangeland. This was attributed to the reduction in total plant matter yield and greater amount of exposed soil on the heavy grazed range. The rainfall simulator, used as a sprinkling infiltrometer proved a useful tool for measuring runoff, soil loss and infiltration on sloping land.

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A COMPARISON OF THREE GULLY EROSION CONTROL TECHNIQUES

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INTRODUCTION

Various methods for the stabilization of erosion gullies have been developed, with concrete, gabion or rip rap drop structures commonly utilized. The drawback of most of these methods at the farm level is their prohibitive cost. Farm projects are wholly or partially funded by the landowner, and the cost must be reduced to an affordable level to make project construction feasible. The challenge for the designer is to utilize innovative methods and materials which are effective and can meet these financial constraints.

Three projects recently completed, using different methods, have performed reliably and were constructed with minimum expense.

DISCUSSION

Large gullies are the most dramatic evidence of soil erosion by water. If control measures are initiated at an early stage of gully development, soil loss can be prevented and costs minimized. In cases where preventative action is not taken until the gully is established, more extensive measures must be undertaken.

A wide bottomed, well established grassed waterway can be stable, where flow velocity of runoff does not exceed 1.8 m/s and gradient is less than 5% (Smith, 1978, Chow, 1959). For channel gradients greater than 5%, and anticipated flow velocities greater than 2 m/s, more protection than simply channel configuration and vegetative lining is needed to ensure channel stability.

Several types of nylon erosion mats are available for lining channels. These mats work in conjunction with a vegetative cover to provide additional scour protection. The matting provides a permanent or long term reinforcement of the sod cover and is extremely erosion resistant. Since the mat/grass matrix can be used for channels with gradients up to 10%, this is a suitable alternative for the implementation of drop chutes. Mat drop chutes can in some instances replace rock, concrete, or metal pipe drop chutes at a lower cost.

An alternative to a high capacity lined channel or structure is the water and sediment control basin. This type of control utilizes an earth berm constructed across a low area in a field to temporarily store excess water from the watershed. Storing a portion of the runoff reduces the peak flow to a non-erosive level. The stored runoff is released slowly through a controlled outlet and pipeline under the berm. An emergency spillway to carry flows which would otherwise overtop and damage the berm is an important component of these projects. An additional benefit is that eroded soil is deposited in the flooded area and retained on the land. These structures are feasible only when a low area with sufficient storage capacity is present, and are not suitable for projects where slopes are steep and flow volumes are high.

Drop pipe structures are used for high drop, steep gradient locations. These structures consist of a berm and inlet which direct runoff to a pipe. The pipe conveys the

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runoff downslope, to outlet at a location with less gradient. The water attains high velocity, and a stilling basin is required to prevent erosion at the outlet of the pipe. The stilling basin is usually lined with rock rip-rap, to protect the basin and outlet from scour. This type of structure can be costly, especially when large diameter pipe is required to accommodate high flow volumes. If site topography allows, a storage area can be incorporated above the drop inlet. This will increase the capacity of the structure at minimum cost, by storing a portion of peak flows during extreme runoff events. An emergency spillway must be included, to prevent failure and damage of the structure when maximum design flowrates are exceeded.

A large amount of earthwork is usually not required for a gully reclamation project. To install erosion matting or a drop pipe structure, the majority of equipment time will be spent in shaping the gully and grading the bottom to a uniform slope. Installation of erosion matting or a drop pipe is labour intensive and requires a crew on site (Table 2).

DEMONSTRATION PROJECTS

The Marvin Brucks Project

With a horizontal distance of 130 metres and a vertical drop of 30 metres, this is the steepest of the three projects. This project is located on the Kakut creek valley near Peoria in Improvement District #19 Birch Hills (Figure 1). Rycroft series silt loam soils in this area are subject to severe water erosion on sloping land. The watershed area is 72.3 hectares, and a storm with a 25 year return period was calculated to produce a design flow rate of 0.87 cubic metres per second (Table 1).

Table 1. Demonstration Project Specifications

Project	Design Flow Rate (m^3/s)	Vertical Drop (m)	Horizontal Distance (m)	Maximum Slope (%)	Soil Type
Brucks	.87	30	130	23.0	Rycroft Silt Loam
Olsen	.45	11	450	3.6	Athabasca Sandy Loam
Pillar	.68	3	50	6.0	Culp Sandy Loam

A rock drop structure had been constructed in 1986, but it failed during the severe storm that occurred in 1990. A permanent drop structure was required to prevent further advance of the gully. Due to the length and high vertical drop, the maximum allowable velocity for a grassed channel was exceeded, and lining the channel with rock or concrete would be costly. The narrow and deeply incised gully left little room to work. A concrete sewer catch basin with a corrugated metal pipe (cmp) stub cast in place by the manufacturer was used as the inlet. A 400 mm diameter cmp, 100 metres in length, was used for the barrel. At the outlet of the pipe, a short section of 2.5 metre diameter culvert set on end and filled with rock was used as a stilling basin. A berm with an emergency spillway was constructed, to direct runoff to the inlet and protect the structure from overtopping and possible failure.

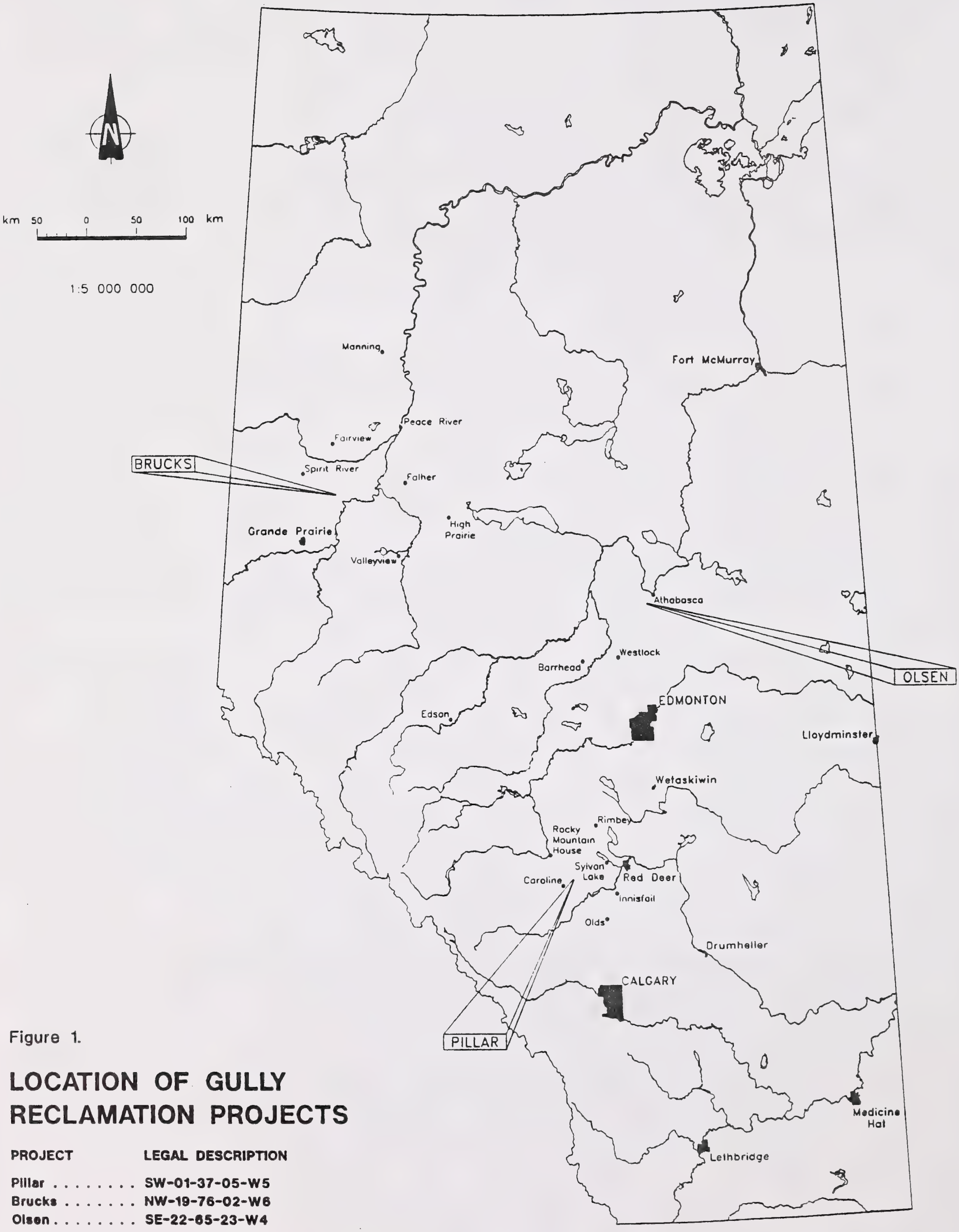

Figure 1.

LOCATION OF GULLY RECLAMATION PROJECTS

PROJECT	LEGAL DESCRIPTION
Pillar	SW-01-37-05-W5
Brucks	NW-19-76-02-W6
Olsen	SE-22-65-23-W4

Equipment included a small crawler tractor and track hoe used for levelling and excavation, and a tractor and scraper which were used to construct the berm. Installation of the 100 metre long culvert pipe and the stilling basin greatly increased the amount of labour required to complete the project (Table 2).

Table 2. Demonstration Project Costs and Labour Requirements

Project	Total Project Cost ($)*	Equipment Cost ($)	Materials and Misc. Costs ($)	Labour (Hours)
Brucks	9652.14	5071.80	4580.34	90
Olsen	13643.00	12227.08	1415.92	20
Pillar	1682.00	500.00	1182.00	46

*Engineering survey and design, construction supervision and labour were provided by Conservation and Development Branch and are not included in costs.

The Kelly Olsen Project

This project is located in the County of Athabasca, near the town of Athabasca (Figure 1). Athabasca series soils in the project area are sandy loam in texture and are vulnerable to water erosion. An eroded gully runs across the 1/4 section and eventually drains into Muskeg creek. A watershed 238 ha. in area produces a design flow rate of 0.93 m^3\s, however the peak flow rate is reduced to 0.45 m^3\s by a 600 mm culvert located upstream of the project (Table 1).

The land is in pasture, and one of the objectives of the project is to store water for stock watering. This made it necessary to include a storage component in the design considerations. The reservoir made it possible to use a small diameter outlet and reduce costs by storing a portion of peak runoff. A natural wide depression at the upstream end of the project was used as the location for the reservoir. The dam was constructed using fill taken from the backflood area. This also increased the storage area of the reservoir. Hickenbottom inlets and a plastic pipe were utilized as a controlled outlet, to restrict outflow and prevent downstream erosion. The Hickenbottom inlet is a plastic riser 15-25 cm. in diameter, with rows of round holes in the above ground portion. The riser is connected to a below-ground outlet pipe. The rate of flow is controlled by the number of holes in the inlet. Different sizes of risers are used to vary the volume of flow as required for each project. For this project, two risers with a combined capacity of .16 m^3/s were specified. The outlet was positioned at the full supply level, which will allow the storage component of the reservoir to fill before outflow occurs. An emergency spillway was also provided, to protect the dam from washout in the event of an extreme runoff event. A track hoe and crawler tractor were utilized for the earthwork. The eroded channel downstream of the structure was repaired and reconstructed with a wide bottom and gentle sideslopes, and seeded to grass to prevent further erosion.

Construction of this project involved a large amount of earthwork, with 480 m^3 of fill required for the dam. A considerable amount of equipment time was also needed to repair the downstream channel. These factors increased equipment costs for the project (Table 2).

Full supply level of the storage component was reached during the first spring runoff.

The Pillar project

The Pillar project is located in the M.D. of Clearwater. This gully erosion control project involved the construction and installation of a mat/grass matrix lined chute. The chute is 50 metres in length with a vertical drop of 3 m (6% slope). The chute is designed to sustain a maximum flowrate of .68 m3/s. Soils in the area are classified as Culp sandy loam, and are erosion prone. The outlet for this project is the North Raven River, one of Alberta's best brown trout fishing streams, and the project has the added benefit of reducing siltation in this important fish habitat.

The topsoil was first stripped and stockpiled, and the gully reshaped and graded to the 6% slope using a small crawler tractor. A rock-filled stilling basin constructed at the downstream end of the matting is designed to dissipate energy with a hydraulic jump before the chute re-enters the original channel. This downstream portion of the channel is stable due to its flatter slope. The topsoil was replaced and grass was seeded in the channel using a broadcast seeder. Permanent nylon matting was installed in the centre of the channel, where flow will be concentrated and velocity will be highest. Biodegradable coconut fibre/straw matting was used on each side of the nylon matting. The matting will protect the channel from erosion until the grass becomes established, and form a permanent protective mat when the grass roots intertwine with the nylon fibres. Grass cover will be adequate to protect the channel sides when the biodegradable matting decomposes in several years time.

Wet conditions after construction enabled the grass to germinate and establish quickly.

CONCLUSIONS

1. Installation of gully erosion control works can be accomplished effectively by an experienced contractor but will pose difficulties for the average farmer.
2. Professional expertise is needed to plan, design and implement gully erosion installations.
3. Erosion control mats need manpower for installation. Earth moving equipment is needed to shape the eroded gully and to save and respread topsoil. Small earthmoving equipment is advantageous for shaping gullies because of space limitations. Precision during final shaping and during mat installation is crucial to project success.
4. Small dams are effective in capturing runoff and controlling erosion. Earth moving equipment is needed to construct the small dams. Equipment size is dependant upon availability and economics. Limited manpower is needed for the installation of small plastic pipelines. Precision is needed in establishing final crest elevations for dams, spillways, and outlet works.
5. Sewer catchbasin drop structures are simple to conceptualize. Catchbasins and pipe are readily available. Considerable manpower is needed during installation. Catchbasins are heavy and need heavy equipment for lifting. Precision is needed in setting the catchbasin basin invert elevation. Plastic pipe is preferable over steel pipe because it is easier to carry and install within the confinement of a gully. Small earthmoving equipment is advantageous for pipeline bed preparation in the gully because of space limitations.

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MONTHLY EXTREME RAINFALL INTENSITY, DURATION AND FREQUENCY IN ALBERTA

P. Dzikowski[47], M. Tautchin[1], S. Chetner[1], and J.D. Wilson[48]

INTRODUCTION

In Alberta the time of the heaviest rainfalls (summer) does not coincide with the time when soil is most susceptible to water erosion (spring). Annual data on rainfall intensity, duration and frequency (IDF) are available (Hogg and Carr 1985), but are more useful for engineering design than for soil erosion studies. Soil conservation specialists need monthly rainfall intensity data to supplement surface cover information to assess the effectiveness of soil and crop management alternatives to reduce the risk of soil erosion by water.

This paper describes the data handling and analysis used to prepare monthly extreme rainfall IDF information for Alberta.

METHODS

Daily maximum rainfall intensity data for 9 durations, for period of record were obtained in digital files from Environment Canada. The 9 durations were 5, 10, 15 and 30 minutes and 1, 2, 6, 12 and 24 hours. In Alberta 47 stations use tipping bucket rain gauges to record rainfall intensity, and 84 use Fischer/Porter weighing precipitation gauges. The daily extreme rainfall intensity files were about 130 megabytes (Mb).

A mainframe computer was used to split the data into smaller groups. The data were analyzed and final products were prepared using SAS/PC (Statistical Analysis System) software, version 6.04, for DOS 5.0 on an IBM PS/2 model 65 personal computer.

The maximum rainfall intensity for each month and for each year was abstracted from the daily data for the period of record at each location. This provided a data set, which we call a group of observations, for every combination of location, duration, and month or year.

The SAS procedure "Means" was used to calculate, for each group of observations, the mean, standard deviation and number of observations of maximum rainfall intensity. The number of observations corresponds to the period of record for the location.

The Gumbel extreme value distribution was chosen to fit to the data. The selection was based on both theoretical support and its use for extreme rainfall analysis in numerous earlier studies (eg. Hershfield, 1962; Dickinson, 1977).

Gumbel location and scale parameters were calculated using the sample mean ($\overline{X}$) and standard deviation (S_x).

$$\text{Gumbel scale parameter} = (\sqrt{6}/\pi)\, S_x \qquad (1)$$

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$$\text{Gumbel location parameter} = \bar{X} - 0.57772\ S_x \qquad (2)$$

The Kolmogorov-Smirnov (KS) Goodness-of-Fit test was used to identify any groups of observations that did not fit the Gumbel distribution. Any station with less than 5 years of data was dropped, since the critical values for the KS Goodness-of-Fit test are valid only for n > 4.

Extreme rainfall intensity (I) values were calculated for specified return periods (T) for each duration (d) with data:

$$I_d = \bar{X}_d + S_x\ K_t \qquad (3)$$

Where K_t is a frequency factor for return period T:

$$K_t = \frac{\sqrt{6}}{\pi}\ (y_t - 0.57772) \qquad (4)$$

Where y_t is the reduced variate:

$$y_t = -\ln(-\ln F_t) \qquad (5)$$

Where F_t is the cumulative probability for the specified return period:

$$F_t = 1 - \frac{1}{T} \qquad (6)$$

Details of the analysis and output procedures, including SAS source code, are found in Tautchin et al. (1991). The monthly and annual IDF data were presented in the form of graphs, tables and maps.

RESULTS

A sample monthly IDF data table is presented in Table I. Several tables can fit on a page and data for selected durations and return periods are easily read.
The SAS procedure "tabulate" was used to create the tables.

Extreme rainfall intensity data are often presented in graphs. A sample monthly graph is shown in Figure 1. Annual extreme rainfall graphs were made for 104 stations. In Alberta the rainfall season is about 6 months, typically April to September. We did not make 600 full-page monthly IDF graphs because the report would have been too large to distribute. In addition, IDF graphs, with a family of return period lines, can be confusing, and estimating values from the graph can lead to errors. The SAS procedure "gplot" was used to create the graphs.

Extreme value distribution (EVD) graphs were prepared since the seasonal variation of rainfall intensity is of interest. EVD graphs present all the monthly and annual IDF data for one duration, as in Figure 2. The EVD graphs for most stations display the seasonal variation of extreme rainfall intensity. Rainfall intensities increase from spring to summer, usually peak in July, then drop off again toward the fall.

Table I: May rainfall intensity (mm/hour) at Edmonton Municipal Airport for selected durations (minutes) and return periods (years).

Duration (min)	Return Period (years)					
	2	5	10	20	25	50
5	18.0	26.4	32.0	37.3	39.0	44.3
10	12.8	19.9	24.6	29.1	30.5	34.9
15	11.1	17.3	21.4	25.4	26.6	30.4
30	8.3	12.6	15.5	18.3	19.1	21.8
60	5.7	8.3	10.0	11.7	12.2	13.8
120	3.7	5.4	6.4	7.5	7.8	8.8
360	1.8	2.5	2.9	3.4	3.6	4.0
720	1.0	1.4	1.6	1.9	2.0	2.2
1440	0.6	0.9	1.2	1.4	1.5	1.7

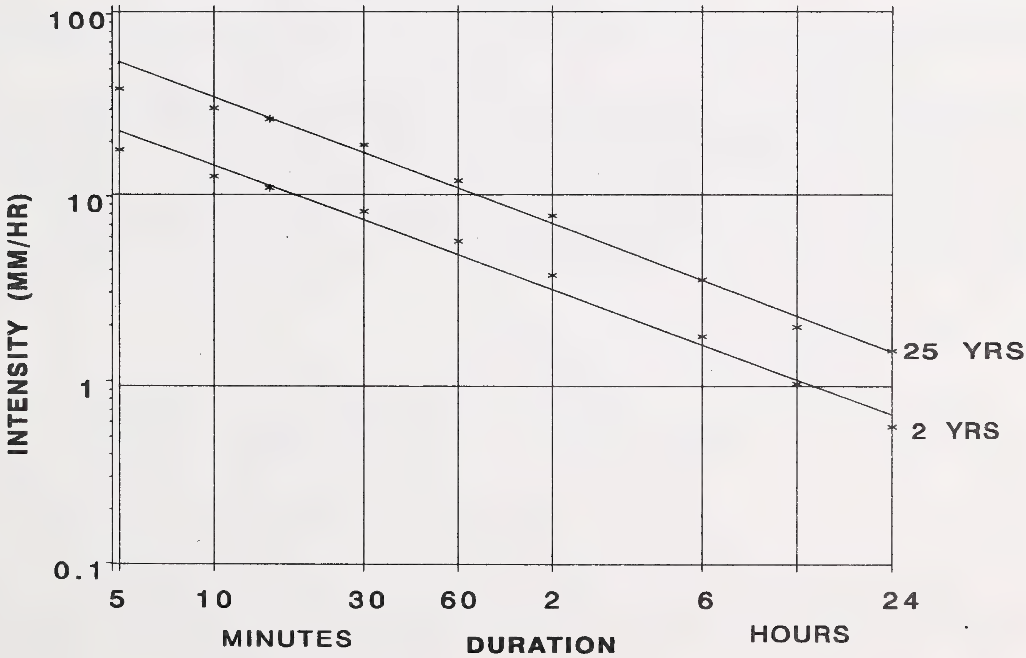

Figure 1: May extreme rainfall intensity, duration and frequency for Edmonton Municipal Airport.

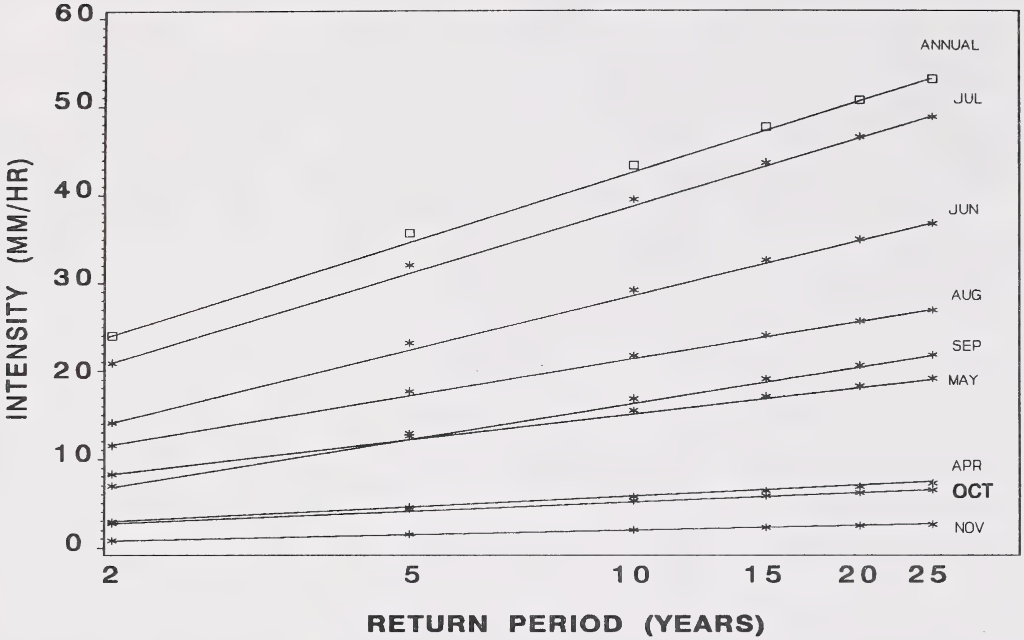

Figure 2: Monthly and annual extreme value distributions for 30 minute duration at Edmonton Municipal Airport.

This pattern is clearer when the rainfall intensity is plotted for one duration and one return period, as shown in Figure 3. The seasonal variation of rainfall intensity is similar to the seasonal pattern of monthly total rainfall (Dzikowski and Heywood 1990).

The Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) and the Erosion Productivity Impact Calculator (EPIC) model (Sharpley and Williams 1990) are used to assess soil and crop management alternatives to reduce the risk of soil erosion (Izzauralde et al. 1991). Quantifying soil erosion by water in Alberta is an important part of farm soil and water conservation planning.

Rainfall intensity, the most important factor contributing to water erosion of soil, is used to determine the rainfall erosivity parameter (R) used by the USLE. The R parameter was calculated for each month at each location using the rainfall intensity (P) for the 2 year return period, 6 hour duration, following the procedure described by Kachanoski and de Jong (1985).

$$R = 0.17\ P^{2.2} \qquad (7)$$

The R value was presented in a table of monthly values for over 100 locations (Tautchin et al. 1991).

Although monthly extreme rainfall IDF data was available for over 100 locations in Alberta, interpolating between data points remained a problem. Our solution was to map the monthly statistics for the 30 minute duration extreme rainfall rate. The 30 minute duration was selected because it is used to calculate the R parameter in the USLE. The

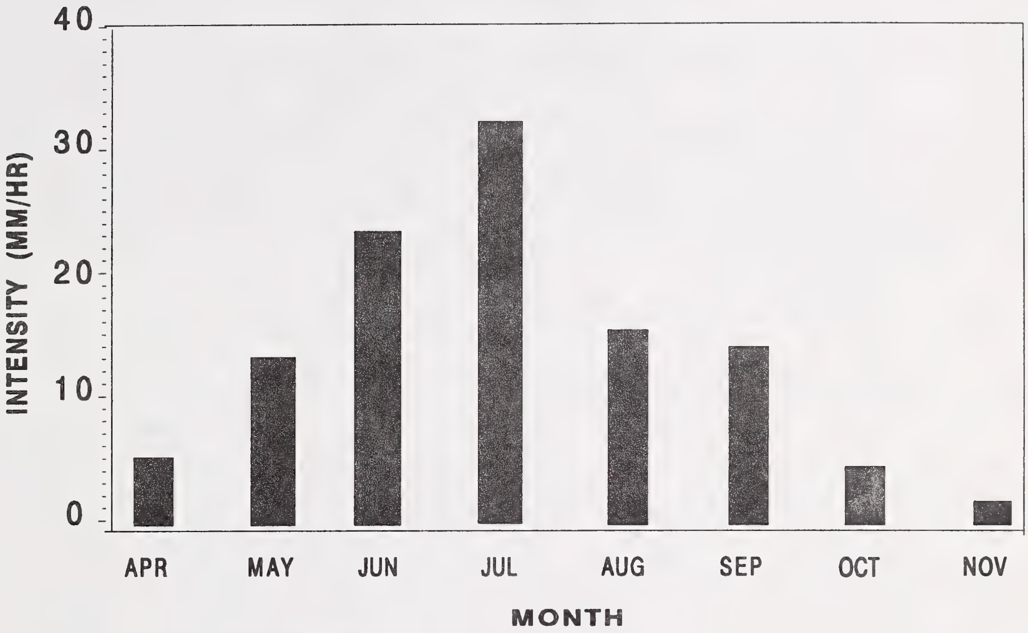

Figure 3: Monthly extreme rainfall intensity for 30 minute duration, 5 year return period at Edmonton Municipal Airport from April to November.

mean and standard deviation combined with an appropriate frequency factor provide the rainfall intensity for any return period. The procedure is shown in equations 3 to 6.

Twenty two maps in total, mean and standard deviation for each month and the year, were prepared. Figure 4 is a sample map. Tautchin and Dzikowski (1993) contains the maps, each with a table of frequency factors, and instructions on how to calculate the rainfall intensity for any required return period.

SUMMARY

Monthly extreme rainfall intensity data for Alberta can now be combined with surface cover information to assess the severity and extent of soil erosion seasonally. Monthly IDF data can help reduce the risk of soil erosion by matching soil and crop management alternatives to the rainfall intensity expected for the time of year. The monthly data allow field results obtained using a rainfall simulator (Nolan and Goddard 1992) to be interpreted in terms of likelihood of occurrence. Extreme rainfall intensity data are used to determine the rainfall erosion index parameter, which is a required input to the Universal Soil Loss Equation. Maps are available to provide reasonably estimated values of monthly extreme rainfall intensity for any location in Alberta.

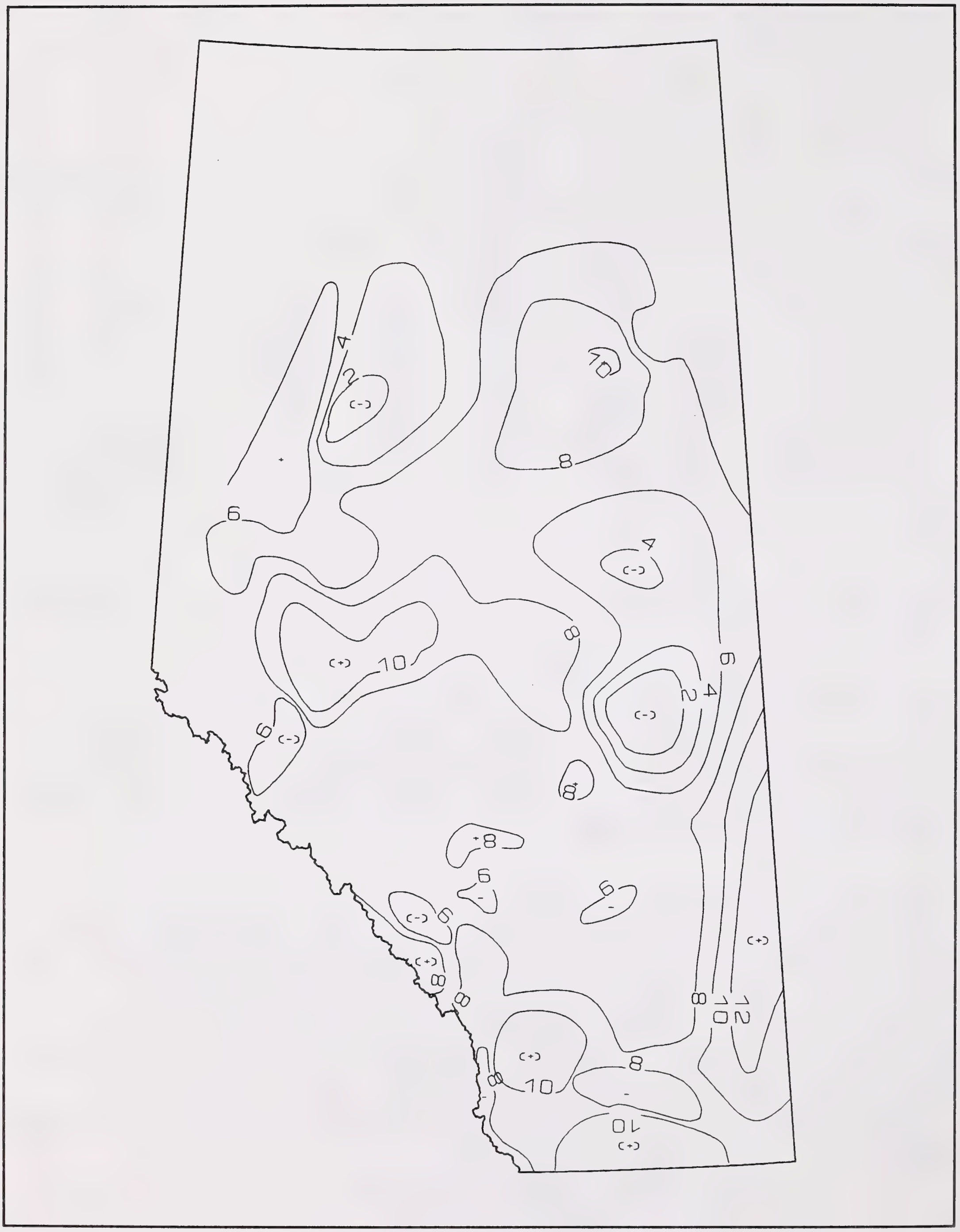

Figure 4: Map of mean May extreme rainfall intensity (mm/hr) for 30 minute duration in Alberta, Canada.

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CONSERVATION - FIELD SHELTERBELTS

SOIL CARBON AND MOISTURE CONTENT NEAR FIELD SHELTERBELTS IN ALBERTA

J. Timmermans[49], J.W. Laidlaw and C. Sprout

ABSTRACT

During spring, 1993, soil samples from 2 fields adjacent to field shelterbelts were sampled to a depth of 0.9 or 1.2 m for determination of gravimetric moisture content. Soil moisture at 1 H was depleted and there was no evidence of soil water recharge from snow drifts. In a second study, total organic carbon (TOC) content was determined in 0-15 cm soil samples from 9 sites located throughout Alberta. Organic carbon was greatest in (0 H) and near (1 to 10 H) field shelterbelts and least in the open field (20 H).

INTRODUCTION

Field shelterbelts are recognized to have a definite impact on wind erosion. Recently, the emphasis on the benefits of field shelterbelts has broadened from the single purpose of erosion control to multi-purpose use and agricultural sustainability.

Moisture conservation by shelterbelts includes reduction of evapotranspiration and increased trapping of snow (Staple and Lehane, 1955). Protected areas leeward of shelterbelts can receive 2.5 to 3 times as much moisture from snow as unprotected land (Panfilov, 1937). Shelterbelts can also prolong snowmelt on fields and reduce moisture loss through runoff (Chernikov, 1951) and sublimation (Zykov, 1951). Despite recharge of soil moisture by shelterbelts, they usually deplete subsoil moisture in a zone 1 to 1.5 tree heights (H) on either side of the belt (Stoeckeler and Bates, 1939; Stoeckeler and Dortignac, 1941).

Other than slowing or preventing soil erosion, little information exists on the long term effects of shelterbelts on soil properties. Shelterbelts can trap saltating particles from adjacent fields, leading to increased organic matter (OM) in and near belts by deposition. Leeward of shelterbelts, increased crop growth in the sheltered area (3 to 15 H) (Staple and Lehane, 1955) may result in higher soil OM from root growth and residues. Kort (1988) found OM was higher near shelterbelts and suggested increased vegetative growth and reduced erosion over many years were probably responsible.

In order to quantify the effect of field shelterbelts on soil moisture and soil carbon content, two studies were conducted. The objective of the first study was to evaluate how field shelterbelts affected soil moisture in a particular spring. The objective of the second study was to determine differences, if any, in the organic carbon content of soils in and near field shelterbelts.

METHODS

During spring, 1993, gravimetric moisture to a depth of 1.2 or 0.9 m was determined on the leeward side (south) of East-West oriented caragana shelterbelts near Vulcan and Acme.

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The samples were taken at 1, 2, 3, 5, 10, 15, 20 and 30 times the height of the shelterbelt (H) along three transects perpendicular to the belts.

In a separate study, soil samples from 9 fields with shelterbelts were taken for analysis of Total Organic Carbon (TOC) content. The fields were located near Vulcan, Crossfield, Carbon, Forestburg and Stony Plain and included Dark Brown and Black soils. At each site, soil samples from 0-15 and 15-30 cm at 0, 1, 3, 5, 10 and 20 H along 4 transects perpendicular to the shelterbelts were taken. The 0-15 cm samples were analyzed for TOC content by Leco furnace (analyses done by Norwest Labs, Calgary).

Differences in soil moisture and TOC values at different distances from the shelterbelts were tested using Tukey's T-Test (LSD) and Duncan's multiple range test ($p=0.05$), respectively.

RESULTS AND DISCUSSION

Available soil moisture (0-90 cm) at two sites in southern Alberta was lowest at 1 and 2 H and variable throughout the rest of the fields (Figure 1). Recharge of soil water by melting of snow drifts was not evident during the spring, 1993 at either location. Below average winter precipitation (Dzikowski, 1993) and low wind speeds probably resulted in little or no snow drift formation leeward of shelterbelts during the winter, 1993. Other research shows that, generally, snow is very shallow from the midpoint of the belt out to about 1 H, is deepest between 1 H and 2 H, then decreases in depth out to around 5 H after which it continues to decrease in depth either gradually (bare surfaces), or maintains a uniform depth across the rest of the field (standing stubble) (Caborn, 1958; Frank et al., 1976; McMartin et al., 1974; Staple and Lane, 1955).

Total organic carbon (TOC) content of soil was greatest in and near field shelterbelts (Figure 2). Soils with the lowest carbon content were located in the open field. Increased organic matter (OM) in and near shelterbelts, especially at the southern Alberta sites, was likely due to trapping of saltating particles. Also, lack of tillage, leaf fall and vegetative growth could contribute to increased OM in the shelterbelts. The high OM in soils in the 1 H area would also reflect deposition of saltating particles and, perhaps, leaf fall. There was an apparent increase (although not significant at $p=0.05$) in soil C at 3 to 10 H over the open field (20 H). This area would benefit from reduced wind erosion and increased crop growth, which may, over the long term, contribute to increased organic matter. Deposition of wind born soil could also occur in the 3 to 10 H area to increase organic C.

CONCLUSIONS

Recharge of soil moisture from melting of snow drifts did not occur leeward of two southern Alberta shelterbelts in the spring, 1993. Weather conditions including below normal snowfall and wind speeds were likely the reason. Total organic carbon content of soils in and near field shelterbelts in Southern and Northern Alberta were greatest in (0 H) and near the belts and lowest in the open field (20 H). Trapping of saltating particles, absence of tillage and leaf fall likely contributed to elevated OM in and near shelterbelts.

ACKNOWLEDGEMENTS

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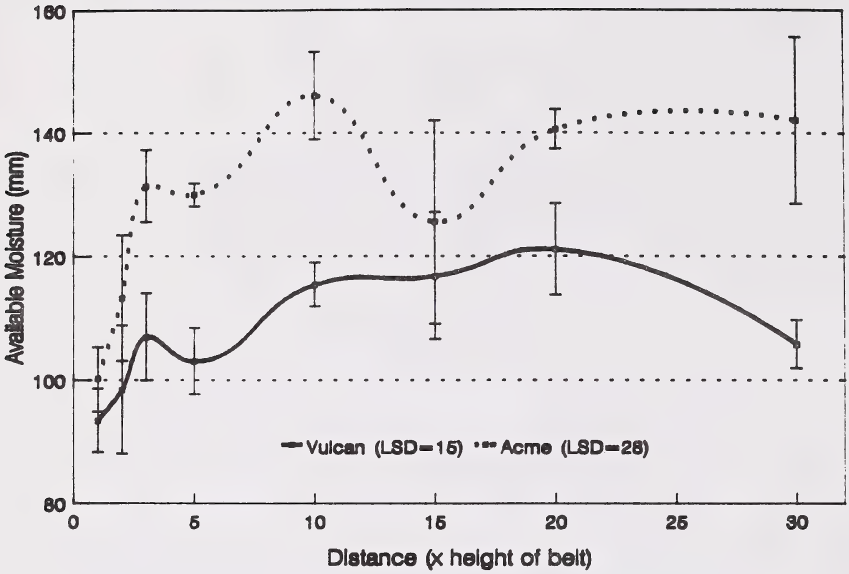

Fig. 1. Available spring soil moisture (0-90 cm) at two sites in southern Alberta in 1993.

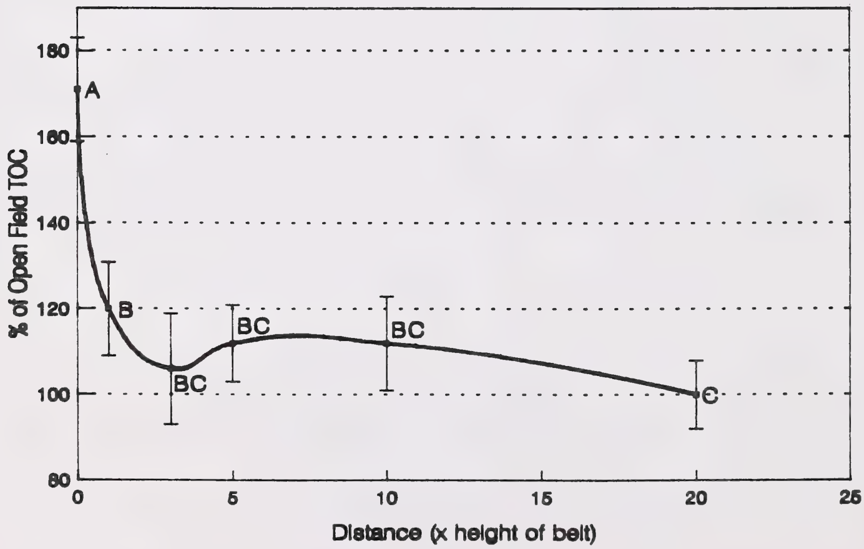

Fig. 2. The effect of field shelterbelts on TOC (0-15 cm) in 1993. Points with the same letter are not significantly different (p=0.05) using Duncan's Multiple Range Test.

EVALUATION OF CROP YIELDS ADJACENT TO FIELD SHELTERBELTS IN ALBERTA

J. Timmermans[50], J.W. Laidlaw and C. Sprout

ABSTRACT

In 1993, crops from 42 sites in Alberta were sampled to evaluate the effect of field shelterbelts on crop yields. Generally, relative increases in crop yields compensated for the area taken up by field shelterbelts with a 2% increase in yield in the protected area over the open field. However, response of crops to field shelterbelts was variable throughout the province with yields ranging from an increase of 19% to a loss of 17% at different sites.

INTRODUCTION

Field shelterbelts protect soils and crops by slowing and diverting wind (Bates, 1917). Shelterbelts have been shown to affect wind velocity for a distance of 30 times their height (Bates, 1911; Hagen and Skidmore, 1971a and b). However, the zone in which crops generally show a response is only about half that distance (Stoeckeler, 1962). Reported effects of shelterbelts on crop yields vary greatly depending on location and crop (Greb and Black, 1961). On the Canadian Prairies, data collected over 9 field seasons by Staple and Lehane (1955) indicated a positive impact of shelterbelts on wheat yields. Kort (1987) reported a 47 kg ha^{-1} y^{-1} (4.3 bu ac^{-1}) increase in wheat yields during three cropping seasons on two fields in Saskatchewan. Bonnefoy and Bonnefoy (1965) found a 76 kg ha^{-1} (6.9 bu ac^{-1}) increase in wheat yields leeward of shelterbelts in Manitoba during 9 field years of research.

Most of the benefit to crops from shelterbelts is related to moisture conservation (Frank et al., 1976). Protected areas can receive 2.5 to 3 times as much moisture from snow as unprotected land (Panfilov, 1937). Also, shelterbelts can prolong snow melt on fields and reduce moisture loss through runoff (Chernikov, 1951) and sublimation (Zykov, 1951).

The objective of this study was to evaluate the effect of field shelterbelts on crop yields in Alberta.

METHODS

Crop yield and soil sampling sites were selected on the basis of uniformity, maturity and size of field shelterbelts as well as uniformity of crops and soils. Topography and proximity to other structures or trees were also considered. The sites were located in Southern, Central and Northern agricultural regions of Alberta and the crops surveyed included wheat, barley, oats and canola.

In all, 42 sites were sampled. Thirty-eight of the sites in the study had planted, single

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row belts, while 3 were natural belts (poplar) and only one belt had two rows. Twenty-two of the shelterbelts were caragana and 9 were poplar. Orientation of the shelterbelts included 18 N-S belts and 24 E-W belts (Figure 3).

Crop yields were determined at different distances along three transects perpendicular to the shelterbelt. Straw and grain covering 1 or 2 m^2 were harvested by hand at 0.5 (when possible), 1, 2, 3, 5, 10, 15, 20 and 30 times the height (H) of the perspective shelterbelt along each transect. The samples were put into cotton bags and hung to cure for 1 to 2 months after which, the samples were threshed and the grain weighed. The grain yield at each H was calculated as a percentage of the assumed open field yield, the average of 20H and 30H yields, to obtain relative yields for each site.

Open field yield was compared to actual yield. The actual yield included the area taken up by half the width of the shelterbelt out to 30H. Differences between open field and actual yields were tested using Tukey's T-test (LSD, $p=0.05$, 0.10, 0.20) for each site and soil zone.

RESULTS AND DISCUSSION

On the whole, shelterbelts increased crop yields enough to compensate for the area they occupied, averaging a 2% (± 14) increase in yield over open field yields. The variability between sites was quite large. Of the 42 sites sampled, 7 had increased yields ($p=0.05$) in the 0 to 30 H area over the open field with increases of 8 to 18%. However, crop yields at 5 sites had decreased yields ($p=0.05$) in the protected area of 4 to 17%. Neither yield increases nor decreases were specific to any one type of belt, orientation, crop or region.

In Alberta, crop yield increases during the previous three years (Figure 1) were considerably greater than those of 1993. The average increases in yield of the protected area (0 to 20 H) in 1990, 1991 and 1992 were 11%, 4% and 21%, respectively (Timmermans, 1993). The 1993 Alberta yields were also lower than those reported in previous years elsewhere on the Canadian Prairies (Kort, 1985; Kort, 1987; Staple and Lehane, 1955; Pelton, 1976).

The differences between years in crop response to shelterbelts can probably be attributed to climate. A lack of snow, wind or both would result in less available moisture for crop growth in the protected area. During 1993, the winter months (January to May) had below average precipitation while precipitation was above average during the summer (Dzikowsky, 1993). Also, soil moisture determinations (data not shown) during the spring, 1993, at Vulcan and Acme, showed no significant recharge of soil moisture had occurred to the leeward of shelterbelts. This indicated that significant snow drift formation behind shelterbelts had not occurred during the winter.

Crop response to shelterbelts tended to be more positive in the Brown soil zone than in other soil zones in the Province (Figure 2). Also, yields to the leeward of shelterbelts were affected farther into the field (> 15 H) than windward of shelterbelts (Figure 3) and North-south belts appeared to be more effective in increasing yields than E-W belts.

CONCLUSIONS

In 1993, an average of crop yields for 42 sites showed a 2% increase in yield in the

protected area from the open field. Yields ranged from an increase of 18% to a loss of 17% in the protected area of shelterbelts. Relative yield increases in 1993 were lower than yields measured in previous years in Alberta and by others on the Canadian prairies. Below average winter snowfall and drifting and above normal summer precipitation were likely the reason for poor crop response to shelterbelts in 1993. More years of research are required to build a reliable data base from which Alberta farmers can make decisions on shelterbelt planning.

ACKNOWLEDGEMENTS

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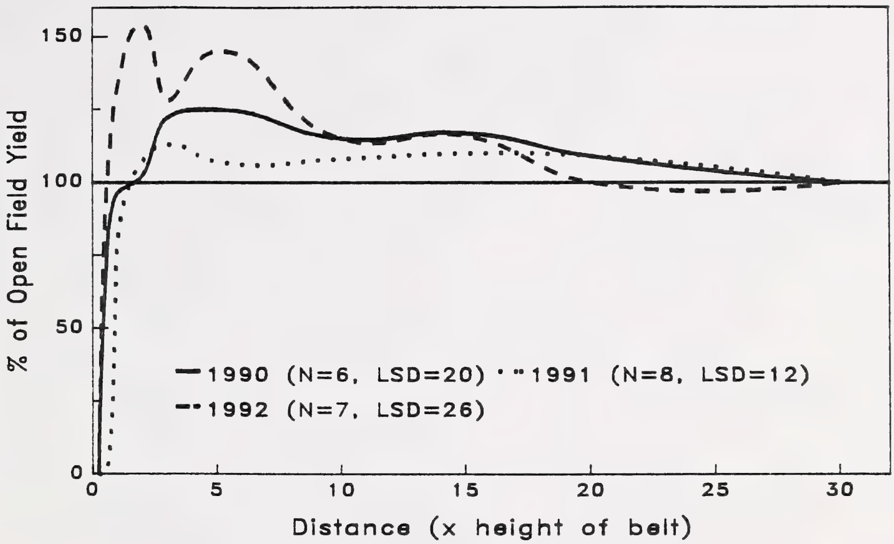


Fig. 1. The effect of field shelterbelts on leeward crop yields over three years.

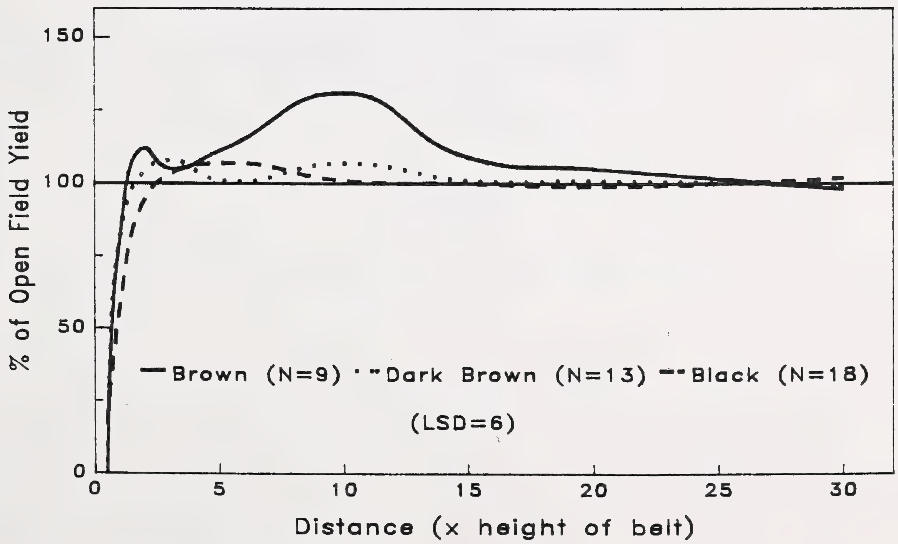
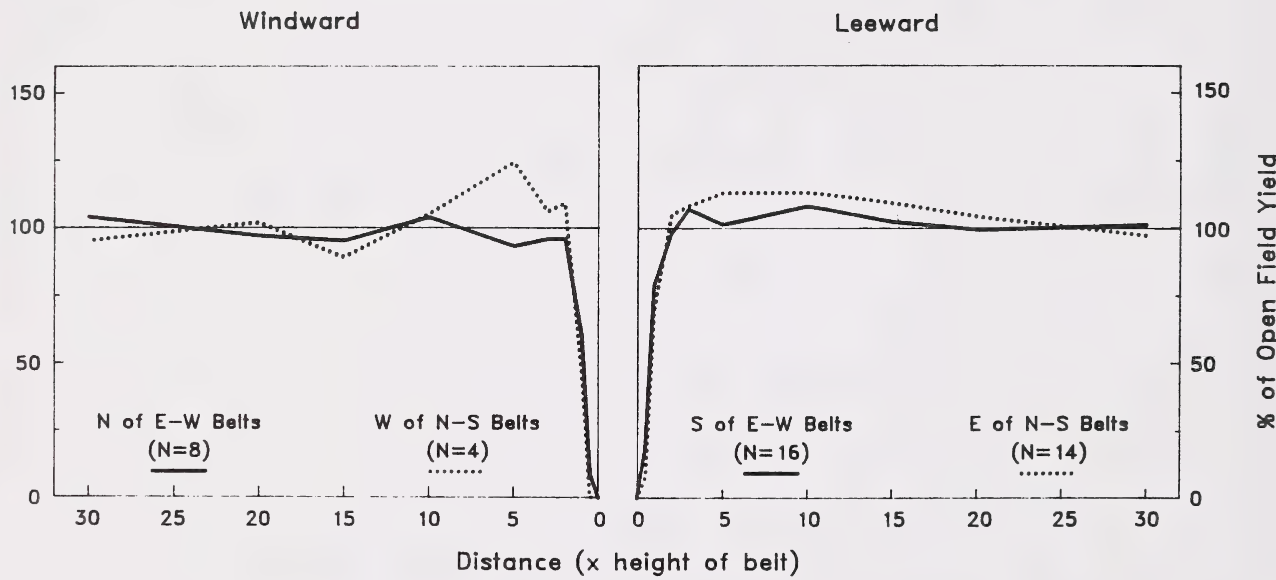


Fig. 2. The effect of field shelterbelts on crop yields in three soil zones in 1993.



ig. 3. The effect of field shelterbelt orientation on leeward and windward crop yields in 1993.

WATER QUALITY

MANURE AND NUTRIENT MANAGEMENT TO SUSTAIN GROUNDWATER QUALITY NEAR FEEDLOTS

K.M. Riddell, D.R. Bennett and S.J. Rodvang[51]

INTRODUCTION

The objectives of this four year study in the County of Lethbridge are:

1) To develop improved manure and nutrient management practices to maximize the economic value of manure and to minimize the impacts of manure spreading on shallow groundwater quality.

2) To develop an awareness program to communicate the findings of this study to the cattle-feeding industry, producers and the general public.

METHODS

Background

Two study sites were selected in the Lethbridge Northern Irrigation District (LNID) portion of the County of Lethbridge in the spring of 1993. Two sites were selected so that comparisons could be made between coarse- and medium-textured soils. Common features at both sites included: level topography, annual cultivation, lack of significant external groundwater and surface water inputs, a water table at depths ranging from 2 to 3 m below ground, a source of irrigation water, and a cooperative landowner.

Soils at the medium-textured site were described as Orthic Dark Brown Chernozemic developed on blanket (> 1 m) deposits of silty clay loam to clay loam textured lacustrine material. Soils at the coarse-textured site were described as Orthic Dark Brown Chernozemic developed on blanket (> 1 m) deposits of sandy loam to loamy sand textured fluvial material.

Experimental Design

Research plots were developed at each site using a randomized block experimental design. Five blocks of six 16 m wide by 16 m long plots were established at each site (Figure 1). Each block contained a replicate of the six treatments - five manure amendment rates of 0, 20, 40, 60, and 120 mg ha^{-1} (wet weight) and one nitrogen (N) fertilizer application of 60 kg ha^{-1} (based on available soil N in the upper 0.6 m and fertilizer N). The treatments were randomly distributed within each block. Separate randomizations were done for the coarse- and medium-textured sites.

Nitrogen fertilizer (urea) will be applied to one half of the control plot at a rate of 120 kg ha^{-1}. This rate corresponds to an amount that producers typically apply for silage barley. An additional 120 kg ha^{1-} of N fertilizer will also be applied to one half of the 60 kg ha^{-1} treatment to represent an optimum rate of N based on crop requirements. Urea will also be applied to half of each manure treatment at a rate sufficient to bring the available soil N

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[z]BMP= Best management rate; Mx= Rate of manure, Mg/ha; Fx= Rate of urea-N, kg/ha.

Figure 1. Plot plan of randomized manure and fertilizer treatments

within the upper 0.6 m, manure N and fertilizer N to a target level of 180 kg ha^{-1}, a best management practice (BMP) estimate. All subtreatments will be randomly assigned within each treatment. Urea will be deep banded in the spring prior to seeding in 1994, 1995 and 1996.

Groundwater Instrumentation and Sampling

One 3 m long piezometer was installed in each subtreatment in the spring of 1993 near the centre of each subplot. The piezometers were slotted below 1 m and the hole around the piezometers was backfilled with sand to 1 m and bentonite from 0.1 to 1 m. Groundwater samples were collected monthly in May, June, July and October and were analyzed for NO_3-N, chloride (Cl), electrical conductivity (EC) and pH (Rhoades 1982). Annual monitoring of groundwater quality in 1994, 1995 and 1996 will be conducted on a monthly basis from April to October.

Soil Sampling and Analyses

Soil samples were collected in the fall of 1993 prior to the application of manure and will be collected again in the fall of 1994, 1995 and 1996 at 6 and 10 m along a transect down the centre of each subtreatment. Composite samples were taken from the two profiles in each subtreatment at depths of 0 to 0.15, 0.15 to 0.30, 0.30 to 0.6, 0.6 to 0.9, 0.9 to 1.2 and 1.2 to 1.5 m.

Field moist soil samples (10 g) were extracted with 100 ml of 2 M KCl on the day of soil sampling and ammonium and NO_3-N content were determined within 24 h by colorimetry with a Technicon TRAACS 800 auto-analyzer. Soil samples were also analyzed for pH, EC, soluble cations (calcium, magnesium, sodium and potassium) and soluble anions (bicarbonate, carbonate, sulfate and chloride) in the saturation paste extract (Rhoades 1982).

Application of Manure

Fresh, feedlot manure was applied at both sites in the fall of 1993. The manure was incorporated by discing into the upper 0.15 m of the soil profile immediately following application. Five samples of manure were collected at each site during fall application.

Statistical Analyses

Preliminary analyses on background soil chemistry consisted of calculating mean EC, SAR, Cl, and NO_3-N from saturated extracts and mean NO_3-N, NH_4-N, and mineral-N (NO_3-N + NH_4-N)(minN) from KCl extracts for each subtreatment. Analysis of variance (ANOVA) on log transformed data, using a randomized block design, was then done to check the significance of the subtreatment effects. Subtreatment means were compared using a Tukey test ($p < 0.05$), if the subtreatment effect was significant ($p < 0.05$).

Preliminary analyses on background groundwater chemistry consisted of calculating mean EC, Cl and NO_3-N for each subtreatment from groundwater samples collected on October 18, 1993. Subtreatment means were then compared using the same statistical procedures described for the soil chemical analyses.

PRELIMINARY RESULTS

Soil Chemistry

Comparison of soil chemistry means showed no significant differences between

Table 1. Comparison of subtreatment mean values for soil chemical parameters at the medium-textured site

Soil Extract	Parameter	Depth (m)	F180	F60	M0F0	M0F120	M120BMP	M120F0	M20BMP	M20F0	M40BMP	M40F0	M60BMP	M60F0
			Subtreatment[z]											
Saturation Extract	EC dS/m	0.00-0.15	0.76	0.72	0.64	0.71	0.81	0.77	0.69	0.67	0.81	0.78	0.78	1.09
		0.15-0.30	0.71	0.69	0.60	0.87	0.72	0.69	0.70	0.72	0.59	1.09	0.66	0.81
		0.30-0.60	1.20	1.42	0.68	1.14	1.35	1.26	0.75	1.05	0.71	1.37	0.79	1.17
		0.60-0.90	1.73	2.41	0.95	1.77	1.63	1.69	1.39	1.67	0.95	1.80	1.70	2.01
		0.90-1.20	2.32	3.13	1.72	2.36	2.52	3.22	2.16	2.63	1.65	2.18	3.07	3.44
		1.20-1.50	3.31	4.15	2.20	2.49	3.55	3.57	3.84	3.19	2.47	3.39	3.34	3.81
	SAR	0.00-0.15	0.58	0.58	0.50	0.66	0.66	0.52	0.64	0.58	0.48	0.62	0.54	0.64
		0.15-0.30	1.10	1.14	1.08	0.94	0.96	1.04	1.10	1.16	1.00	0.94	1.00	1.22
		0.30-0.60	1.10	0.94	1.10	1.00	1.00	1.08	1.04	1.06	1.20	1.00	1.08	1.16
		0.60-0.90	0.98	0.98	0.82	0.76	1.10	0.92	0.96	0.98	0.96	1.10	0.90	1.30
		0.90-1.20	1.04	1.24	0.80	0.82	1.18	0.90	1.02	0.78	0.92	1.22	0.80	1.32
		1.20-1.50	0.88	1.52	0.72	0.80	1.02	0.82	0.88	0.62	0.92	1.12	0.88	1.06
	Cl meq/l	0.00-0.15	0.58	0.42	0.54	0.60	0.46	0.56	0.42	0.56	0.58	0.54	0.58	0.64
		0.15-0.30	0.64	0.54	0.64	0.60	0.54	0.60	0.50	0.58	0.76	0.66	0.58	0.70
		0.30-0.60	0.38	0.34	0.38	0.30	0.32	0.40	0.34	0.30	0.46	0.42	0.46	0.52
		0.60-0.90	0.22	0.18	0.14	0.12	0.14	0.14	0.12	0.10	0.20	0.14	0.18	0.14
		0.90-1.20	0.18	0.14	0.12	0.10	0.12	0.10	0.10	0.12	0.14	0.10	0.10	0.12
		1.20-1.50	0.10	0.12	0.14	0.10	0.10	0.12	0.10	0.12	0.12	0.10	0.12	0.10
	SAT NO3-N kg/ha	0.00-0.15	0.03	0.03	0.00	0.01	0.06	0.05	0.04	0.03	0.00	0.02	0.07	0.05
		0.15-0.30	0.83	0.32	0.71	0.52	0.56	0.22	1.70	1.85	4.32	2.38	2.38	1.68
		0.30-0.60	10.81	6.32	11.29	6.42	8.33	4.48	22.86	10.84	16.53	7.36	12.95	13.13
		0.60-0.90	7.36	6.82	5.15	4.47	5.30	3.30	8.64	7.14	9.86	4.38	4.24	4.39
		0.90-1.20	8.09	3.23	3.48	2.37	3.34	2.43	2.78	2.04	3.06	2.16	3.33	2.02
		1.20-1.50	2.23	2.32	3.88	2.00	2.77	2.36	1.75	2.08	2.74	1.93	2.64	2.25

[z] BMP= Best management rate; Mx= Rate of manure, Mg/ha; Fx= Rate of urea-N, kg/ha. [y] Min N = Mineral Nitrogen (KCl extract NH4-N + NO3-N)

Table 2. Comparison of subtreatment mean values for soil chemical parameters at the coarse-textured site

Soil Extract	Parameter	Depth (m)	F180	F60	M0F0	M0F120	M120BMP	M120F0	M20BMP	M20F0	M40BMP	M40F0	M60BMP	M60F0
			Subtreatment [z]											
Saturation Extract	EC dS/m	0.00-0.15	0.94	0.92	0.89	0.83	0.95	0.89	0.92	0.98	0.84	0.80	0.91	0.85
		0.15-0.30	0.68	0.70	0.69	0.72	0.69	0.76	0.73	0.78	0.68	0.66	0.76	0.65
		0.30-0.60	0.57	0.57	0.55	0.53	0.59	0.62	0.57	0.64	0.54	0.62	0.69	0.58
		0.60-0.90	0.72	0.76	0.71	0.82	1.19	0.96	0.57	1.05	0.66	0.87	1.31	0.66
		0.90-1.20	1.26	1.37	1.35	1.17	1.74	1.33	0.79	1.23	1.25	1.65	1.58	1.21
		1.20-1.50	1.44	1.47	2.22	1.45	2.18	1.77	0.86	1.36	1.20	1.71	1.82	1.43
	SAR	0.00-0.15	0.28	0.32	0.36	0.34	0.28	0.40	0.42	0.34	0.40	0.32	0.52	0.32
		0.15-0.30	0.46	0.48	0.42	0.42	0.42	0.56	0.52	0.60	0.48	0.54	0.72	0.56
		0.30-0.60	1.64 ab	1.66 ab	1.06 ab	0.98 b	1.42 ab	1.38 ab	1.24 ab	1.78 ab	1.10 ab	1.40 ab	1.98 a	1.50 ab
		0.60-0.90	1.82	1.90	1.70	1.18	1.56	1.66	1.28	1.44	1.18	1.26	2.02	1.82
		0.90-1.20	0.72	0.74	0.98	0.58	1.26	0.90	0.90	0.80	0.70	1.36	1.28	1.18
		1.20-1.50	0.56	0.56	1.48	1.44	0.76	1.00	0.94	1.06	0.94	1.58	1.10	1.88
	Cl meq/l	0.00-0.15	0.36	0.40	0.38	0.38	0.38	0.42	0.34	0.36	0.34	0.32	0.46	0.36
		0.15-0.30	0.32	0.28	0.26	0.28	0.34	0.38	0.30	0.30	0.32	0.30	0.36	0.26
		0.30-0.60	0.26	0.26	0.20	0.20	0.26	0.38	0.22	0.26	0.24	0.28	0.32	0.26
		0.60-0.90	0.58	0.50	0.24	1.00	1.50	1.26	0.24	1.68	0.50	0.94	2.54	0.24
		0.90-1.20	2.68	3.62	1.72	2.38	3.28	2.68	1.28	2.74	2.34	3.20	3.74	1.86
		1.20-1.50	3.86	4.02	2.46	3.06	2.22	3.46	1.38	3.54	2.28	3.40	3.28	3.02
	SAT NO3-N kg/ha	0.00-0.15	26.31 ab	24.82 ab	17.39 ab	15.60 ab	11.37 b	16.21 ab	22.08 ab	32.95 a	15.77 ab	16.54 ab	17.07 ab	16.12 ab
		0.15-0.30	20.27	21.43	18.58	23.42	15.54	21.63	22.63	23.96	20.31	18.55	21.99	16.45
		0.30-0.60	22.11	21.45	24.56	21.93	37.01	29.15	24.04	26.86	20.87	38.39	41.75	25.12
		0.60-0.90	38.22	46.72	43.46	49.88	96.60	54.99	22.68	56.03	36.61	44.10	79.30	29.82
		0.90-1.20	83.42	105.58	58.02	84.39	103.05	86.66	40.00	93.60	95.76	102.67	82.70	72.93
		1.20-1.50	123.62	120.24	81.45	131.90	164.02	117.70	49.95	89.37	91.04	111.29	108.01	116.85

[z] BMP= Best management rate; Mx= Rate of manure, Mg/ha; Fx= Rate of urea-N, kg/ha. [y] Min N = Mineral Nitrogen (KCl extract NH4-N + NO3-N)
ab = Mean values within a given sampling depth followed by the same letter are not significantly different according to Tukey test ($p<0.05$)

subtreatments at the medium-textured site (Table 1). Comparison of soil chemistry means showed very few differences between subtreatments at the coarse-textured site (Table 2). Significant differences were found between SAR levels in the 0.30-0.60 m depth and saturation extract NO_3-N levels in the 0-0.15 m depth at the coarse-textured site (Table 2).

Mean soil EC and SAR levels in the root zone (0-1.2 m) were generally less than two at both sites. Soil salinity and sodicity should not be limiting factors to crop growth in the first year following manure application at either site.

Soil NO_3-N levels were generally below 10 kg ha^{-1} in all sampling intervals at the medium-textured site (Table 1). Peak soil NO_3-N values ranged from 10 to 20 kg ha^{-1} in the 0.30-0.60 m depth at the medium-textured site.

Soil NO_3-N levels were 20 to 160 kg ha^{-1} in all sampling intervals at the coarse-textured site (Table 2). Peak soil NO_3-N values were 100 to 160 kg ha^{-1} in the 1.20-1.50 m depth at the coarse-textured site.

Groundwater Chemistry

Comparison of subtreatment means for groundwater chemistry from the last sampling date (Oct. 18, 1993) showed no significant differences at either the medium- or coarse-textured sites (Table 3). Groundwater was more saline at the medium-textured site, with EC levels of 5 to 7 dS m^{-1}, as compared to EC levels of 1 to 2 dS m^{-1} at the coarse-textured site.

Groundwater contained higher levels of NO_3-N and Cl at the coarse-textured site as compared to medium-textured one. Mean groundwater NO_3-N levels were 1 to 15 mg L^{-1} at the medium-textured site and 10 to 60 mg L^{-1} at the coarse-textured site (Table 3). Mean groundwater Cl levels were 7 to 20 mg L^{-1} at the medium-textured site and 25 to 110 mg L^{-1} at the coarse-textured site.

Manure Analysis

The mean (n=10) total N content of manure samples taken from both sites was 2.28%. Most of the inorganic N in the manure was in the form of NH_4-N. The mean NH_4-N and NO_3-N contents of the manure were 2793 ppm and 1.6 ppm, respectively. The mean phosphate (PO_4-P) content of the manure was 1414 ppm and the mean carbon/nitrogen ratio was 14.2.

Results of salinity analyses showed the manure to be strongly saline and sodic. Mean EC and SAR levels in the manure were 18.6 dS m^{-1} and 16.6, respectively. The mean moisture content of the manure was 60.2%.

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Table 3. Comparison of subtreatment means for groundwater chemistry determined on Oct. 19 samples taken from the medium and coarse textured sites

		Subtreatment[z]											
Site	Parameter	F180	F60	M0F0	M0F120	M120BMP	M120F0	M20BMP	M20F0	M40BMP	M40F0	M60BMP	M60F0
Medium Textured	EC (dS/m)	5.175	6.150	5.256	5.540	6.270	5.912	5.398	5.105	5.560	6.450	6.018	6.954
	Cl (mg/l)	22.050	13.720	19.600	11.100	12.750	10.560	7.260	7.550	19.460	13.040	10.040	16.760
	NO3 (mg/l)	8.723	10.490	7.464	11.172	8.900	6.498	10.740	0.960	12.474	10.738	14.426	1.288
Coarse Textured	EC (dS/m)	1.158	1.308	1.032	1.164	1.388	1.820	1.242	1.748	0.820	1.082	1.096	1.162
	Cl (mg/l)	58.100	91.320	31.740	27.720	42.540	109.460	23.940	55.980	6.400	14.740	39.600	63.480
	NO3 (mg/l)	37.504	60.234	22.436	48.256	40.832	58.400	15.990	51.978	10.328	8.304	21.244	40.322

[z] BMP= Best management rate; Mx= Rate of manure, Mg/ha; Fx= Rate of urea-N, kg/ha.

NITRATE MIGRATION UNDER LONG-TERM IRRIGATED FIELDS

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INTRODUCTION

The ingestion of nitrate has been linked to health problems, so the limit in drinking water has been set at 10 parts per million (ppm). Nitrate from agricultural sources has degraded groundwater supplies in many areas of North America and Europe (Power and Schepers 1989, Strebel et al. 1989). Very little is currently known about the potential for nitrate to contaminate groundwater in southern Alberta. Nitrate leaching below the root zone to groundwater is affected by management practices such as irrigation scheduling, applying nitrogen fertilizer and manure, and timing of application (Rennie et al. 1993).

A four-year study to examine nitrate leaching in irrigated areas of southern Alberta was initiated in 1993. The study will examine the origin and fate of nitrate in a basin which has been irrigated for up to 70 years (Hendry et al. 1984). Results from the first year of the investigation are presented below.

METHODS

Four sites were selected for study: one larger basin-scale study and three smaller detailed study plots. The basin-scale site is located in the Bow River Irrigation District (Figure 1). Twenty-eight piezometers were installed at ten sites in the study area in 1993, using hollow-stem and solid-stem augers. They were developed by pumping out several well-volumes. Subsurface materials were logged during drilling. Eighty-two piezometers installed during the late 1970's (Hendry et al. 1984) were reclaimed and developed. This was accomplished by digging, repairing, and flushing them with iodide-spiked water to remove impurities. Piezometers were then pumped until all iodide traces were removed. Piezometers are composed of 3 cm diameter PVC, with screen lengths ranging from 0.5 to 6 m. Piezometers are up to 50 metres deep and their locations are shown in Figure 2.

Detailed sites 1, 2, and 3 (Figure 1) were instrumented in October and early November of 1993 with piezometer nests consisting of a water-table well and one to three piezometers. Soil samples were collected at each piezometer nest at regular intervals. Soil extracts (10:1 KCl) were prepared from wet samples on the day of collection, and were analyzed the following morning for nitrate and ammonium. Piezometers in the basin study were sampled once between July and November 1993.

Piezometers at the detailed sites were sampled for groundwater nitrate at the end of November 1993 and the beginning of January 1994. A supplementary sampling for nitrate at site 1 was done at the end of January in 1994.

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RESULTS

Basin-Scale Study

The basin study has a flat to gentle topographic slope (0.4%) to the north, except within one kilometre of the Bow River where the slope increases to 3.7%. Groundwater flow was generally north towards the Bow river, with horizontal gradients similar to the topographic slope.

The overburden thickness ranges from 12 to 46 m, and consists largely of weathered and fractured till with interbedded irregular saturated sandy loam lenses. Dark grey unweathered till was encountered below 30 m depth at the south end and occasionally below 18 m in the middle of the section. The bedrock is composed of interbedded sandstone, shale, claystone and siltstone. From its highest point (MA8), the bedrock slopes at 0.6% northwards and 0.7% southwards (Figure 2).

High concentrations of nitrate in groundwater occurred at many locations in the weathered till (Figure 2). The maximum concentration (200 to 500 ppm NO_3-N) was usually situated about 10 m below the till surface, although four sites exhibited high nitrate at the water table. Groundwater nitrate concentrations tended to be higher in areas where the water table was deeper than 2 or 3 m below ground.

Nitrate was less than 10 ppm NO_3-N in the bedrock, except at test-holes 2990 and 2989, where concentrations of 171 ppm and 386 ppm were measured (Figure 2). These levels were restricted to the upper 5 m of the sandstone bedrock and where the till above was weathered and less than 22-m thick. A sandy loam layer at the base of the weathered till (observed in the logs from MA8, 2990, MA7, and 2989) may have provided a hydraulic connection to the sandstone bedrock.

Nitrate concentrations measured in 1993 were often similar to those measured in 1979 (Hendry 1981) and 1990 (Rodvang 1992), although substantial increases or decreases occurred at many locations.

Detailed Site 1

This quarter-section is owned and managed by a local farmer, and is cropped to a bean, wheat and alfalfa rotation. Groundwater flows to the northwest across the site, parallel to a northwesterly slope of 0.2%. The water table occurred at about 2-m depth over the site. Four piezometer nests were installed to an 8-m depth using augers, in a north-south transect through the centre of the quarter (Figure 3a).

The overburden at site 1 is about 20-m thick and consists of weathered and fractured till, covered with up to 1.5 m of aeolian and lacustrine deposits. Logging of testholes to the north and south of Site 1 suggested sandy water-conducting layers, occurring at depths between 12 and 18 m within the till, may pinch out at Site 1. Discharge gradients encountered at the south end of the site (Figure 3b) may have been caused by the pinching out of these sandy layers.

Soil nitrate concentrations were at or below 10 ppm except at AT4 where levels ranged between 60 and 85 ppm. High soil nitrate levels at AT4 did not decrease below the water table (Figure 3c).

The initial groundwater nitrate analysis (November 1993) showed a plume of up to 400 ppm NO_3-N at the south end of the property, at depths of 5 to 7 m (Figure 3d). Soil nitrate data collected just over a month earlier showed no indication of this plume (Figure 3c).

The November 1993 nitrate plume at AT1 was not detected during the January groundwater sampling (Figure 3), suggesting that the plume had moved beyond the cross-section. Instead, January groundwater analyses showed a plume of 100 ppm NO_3-N at AT4 (Figure 3). Water-table contours suggest the groundwater nitrate plume may originate from sources on the immediate field and adjacent areas to the southeast.

Detailed Site 2

Site 2 is managed as a research plot by agricultural scientists. A silage corn and sorghum rotation has been grown at the site since 1981. The site was planted partly to potatoes and partly to sweet corn in 1993. Approximate yields in 1993 were 40 tonnes/ha for the potatoes and 4.3 tonnes/ha as actual grain for the corn (Bryan Farries, Pers. Commun. 1994).

Urea fertilizer at 168 kg N/ha was applied to the site every spring between 1982 and 1986. The rate was reduced to 134 kg N/ha annual spring application between 1987 and 1993. The soil generally exhibited electrical conductivity (E.C.) and sodium adsorption ratios (SAR) values below those thought to impair productivity (Alberta Agriculture 1983), except at testhole VS3. Rough estimates indicate the 1993 corn crop would use about 100 kg N/ha, while the 1993 potato crop would use about 150 kg N/ha (Janzen Pers. Commun. 1994, Tisdale et al. 1985).

Piezometer nests were installed at 6 locations (Figure 4a), at depths ranging from 1.8 to 8.5 m. The topographic slope was 0.3% to the south. The overburden geology consists of lacustrine sandy loam, turning to sand with depth (0.15 to 5.95-m thick) over till. The weathered clay loam to clay till became dense with depth. The water table occurred at 1.0 to 1.5 m below ground (Figure 4b).

November 1993 water-table contours showed shallow-groundwater flow to the northeast with a gradient of 0.004, despite the southerly slope of the till and ground surface. A north-south running subsurface drain, located 47 m to the east and 1.5 to 2 m deep (Gord Cook, Pers. Commun. 1994), may have directed flow to the northeast. Potentiometric contours over most of the site showed little or no groundwater flow into the till, as shown for VS4 in Figure 4b. However, downward gradients at VS2 and VS3 were slightly higher (Figure 4b) and this suggests the till may be more weathered, possibly because the till is closer to ground surface in this area.

Soil and groundwater nitrate concentrations were generally similar (Figures 4c, 4d and 4e). Both sets of data showed high nitrates (up to 160 ppm NO3-N) near the ground surface, decreasing steadily with depth to less than 10 ppm at depths of 2 to 4 m. High nitrates were restricted to the lacustrine sands except near VS3, where nitrate was detected in the shallow till in groundwater samples but not in soil samples.

Detailed Site 3

Site 3 is also managed as a research plot by agricultural scientists. It has been a plot study of nitrogen fertilizer application rates (0, 50, 100, 200 kg N/ha annually) since 1987, and has been cropped to a wheat-wheat-oats rotation. The measured amount of N removed by the oats and wheat averaged 65 and 79 kg/ha N over the last six years (Jack Carefoot, Pers. Commun. 1994).

Piezometer nests were installed in three replicates of each fertilizer treatment, for a total of 12 piezometer nests. Each nest consisted of one piezometer at a depth of 1.5 to 2 m and a second piezometer between 4 to 4.5 m. Water-table wells were installed in the northwest

and southeast corners of the site (Figure 5a).

The topography slopes gently towards the south-southeast at 0.3%. Up to 0.6 m of aeolian and lacustrine materials cover the till over most of the site. A north-south trending dip in the topographic surface of the till and the water table suggests a buried stream bed may cross site 3. The presence of fluvial sands at JC308 to a depth of 1.3 m below ground surface supports the hypothesis of such a buried channel filled with sandy clay loam. The anomalously low water level and discharge zone at JC217 (Figure 5b) would also suggest such a groundwater drain nearby. It is possible that when the water table rises above the till surface, the buried stream bed may act as a groundwater conduit to the south.

The water table was about 1-m deep and imitated the slope of the till and the ground surface, with an average southerly hydraulic gradient of 0.3%. Recharge gradients up to 0.09 occurred over the northeast quarter of the site, and discharge gradients up to 0.19 occurred in the south and west.

Soil nitrate values above 40 ppm NO_3-N were restricted to the unsaturated zone, and levels decreased below the water table (Figure 5c). The highest soil nitrate concentrations (100 to 300 ppm NO_3-N) were determined within 0.5 m of the soil surface in lacustrine and aeolian sandy clay loam. These samples where taken from the three plots which received nitrogen application rates of 200 kg/ha annually and one plot which received 100 kg/ha nitrogen annually (data not shown). Elsewhere, soil nitrate concentrations did not exceed 24 ppm NO_3-N.

Groundwater nitrate above 10 ppm occurred at all six sites that received 100 to 200 kg/ha nitrogen annually (data not shown). One site that received 50 kg/ha annual nitrogen also exhibited over 10 ppm NO_3-N in the groundwater. Nitrate levels from soil (sampled October, 1993) and groundwater (November, 1994) generally compared well (Figures 5c, 5d and 5e). Nitrate concentrations in groundwater at most locations on the site were relatively stable between the November and January samplings. However, concentrations increased with time at some locations (Figure 5d and 5e).

DISCUSSION

Both detailed sites 1 and 2 showed a discrepancy between the low soil and high groundwater nitrate concentrations. The difference may indicate that nitrate was transported to the groundwater sampling locations between October (when soil was sampled) and November (when groundwater was initially sampled). Alternatively, it is possible that nitrate was transported mainly through fractures, and was thus not present in the soil matrix. Both explanations suggest relatively rapid migration of nitrate through groundwater at Sites 1 and 2. Groundwater nitrate plume locations at Site 3 were only slightly modified by groundwater flow directions, because horizontal gradients were weak and restricted in most cases by the low hydraulic conductivity of the till.

Geologic logs from the BRID study area showed an extremely heterogeneous distribution of sandy and clayey material, compounded by fractures. The geological heterogeneity indicates that the groundwater flow system will be complex, a hypothesis which is supported by the variability in hydraulic gradients exhibited at detailed sites 1 and 2. In heterogeneous groundwater flow systems, collecting piezometer samples at relatively widely spaced intervals of space and time can produce misleading results (Smith and Ritzi 1993). Therefore, significant nitrate movement in the till may not have been previously observed due to the

wide spacing and infrequent sampling of piezometers in the basin-scale study area.

Lethbridge received 444 mm of rain during the growing season (April to September) of 1993, compared with 198 to 302 mm during the growing seasons of 1989 to 1992. Therefore, more nitrate leaching may have occurred in 1993 than in other years due to the abnormally high amount of rain.

CONCLUSIONS

High levels of groundwater nitrate (up to 500 ppm NO_3-N) occurred at several locations in overburden throughout the basin. Groundwater nitrate was elevated only in the top 5 m of sandstone bedrock, and where the till above was weathered, interbedded with sandy loam lenses, and was less than 22-m thick. More detailed study is required to determine the source of elevated groundwater nitrate in the basin.

Detailed Sites 1 and 2 showed nitrate migration through shallow groundwater during the late fall and winter of 1993/94. At site 1 nitrate plumes (up to 400 ppm NO_3-N) appeared to have moved up from the sandy loam lenses below 10 m. These lenses may have terminated at the south end of site 1, with an up-gradient source to the south. Groundwater nitrate was high in lacustrine sands throughout site 2, but occurred in shallow weathered till only at the northeast corner of the study area. Up to 160 ppm NO_3-N occurred near the ground surface, decreasing to less than 10 ppm at depths of 2 to 4 m. Over much of the site, nitrate movement appeared to be restricted to the lacustrine sands. Minimal nitrate migration was detected at Site 3.

Sites 1 and 2 both showed a discrepancy between the low soil and high groundwater nitrate concentrations. This discrepancy, along with groundwater nitrate changes over the three-month monitoring period, suggests relatively rapid migration of nitrate through groundwater. At site 3, soil and groundwater nitrate were concentrated below plots receiving the highest fertilizer application rates (100 to 200 kg N/ha), and nitrate migration appeared to be slower.

Elevated nitrate was more common in groundwater where the water table was deeper than 2 or 3 metres.

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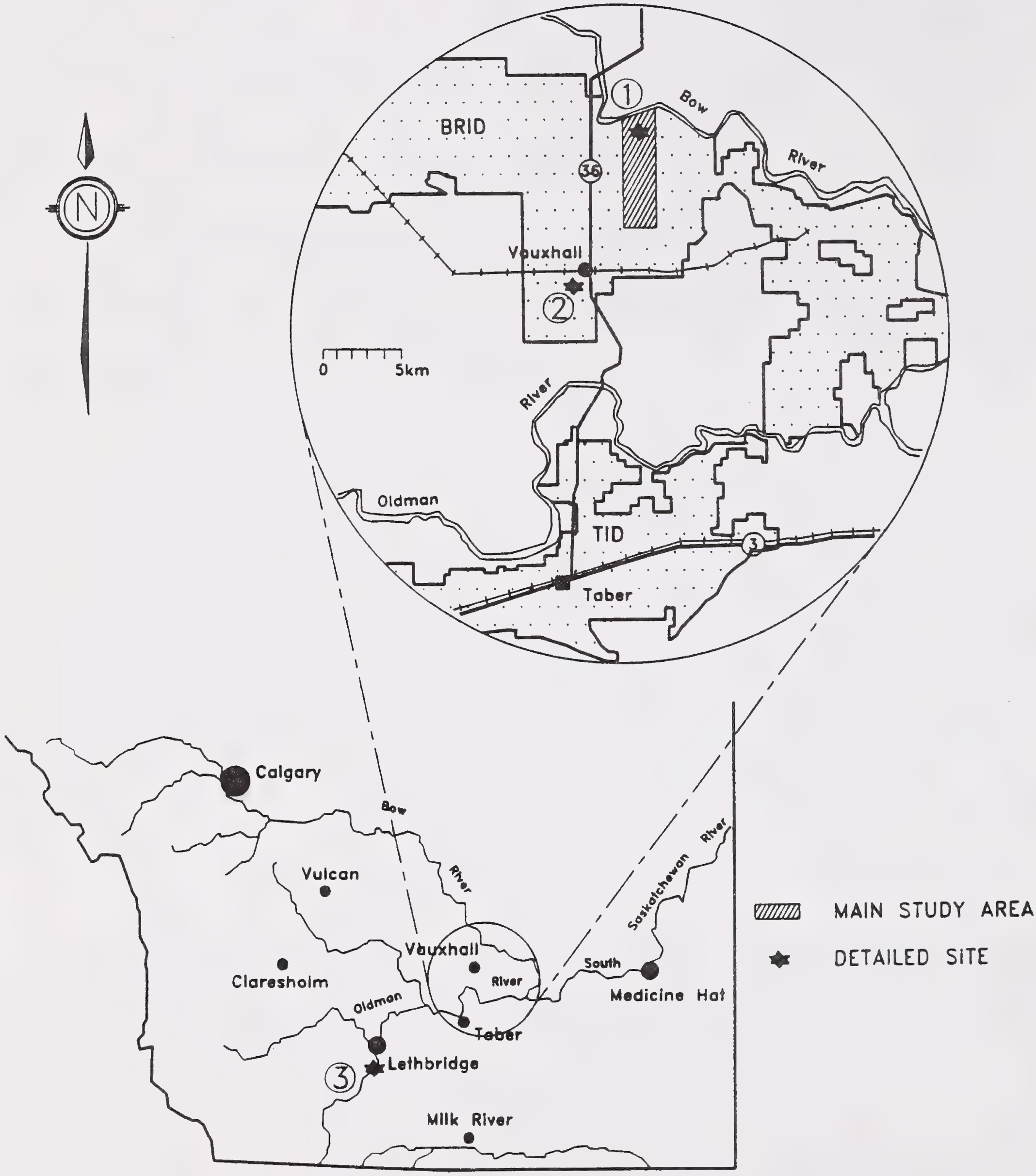


Fig. 1. Location of Study Areas

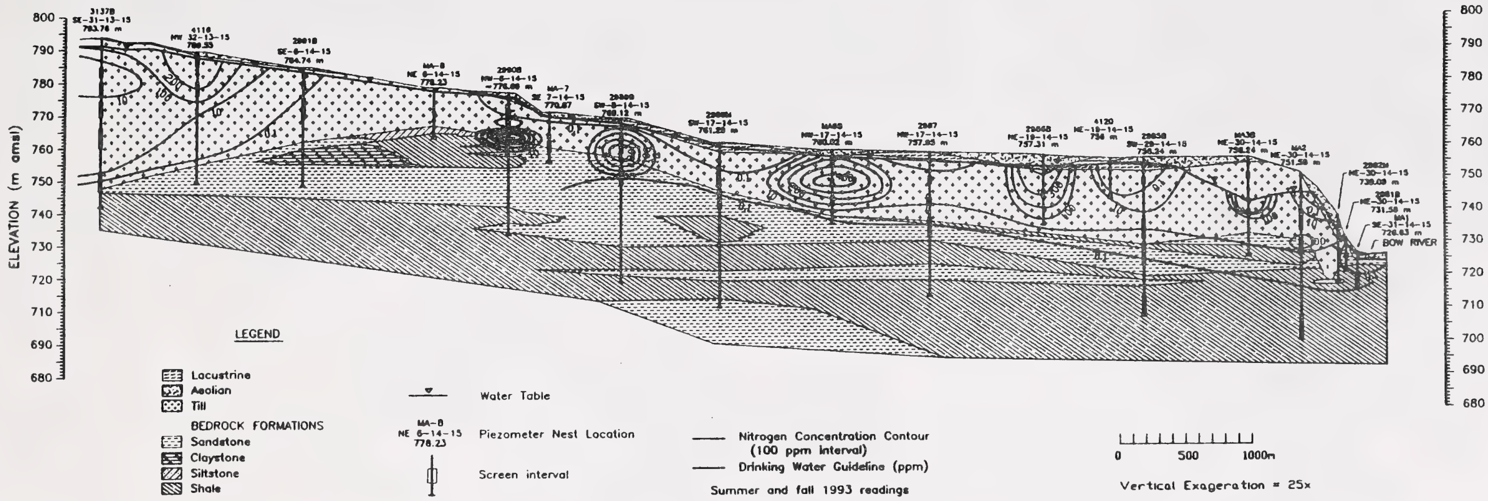


Figure 2. Geologic cross-section through basin-scale study area.

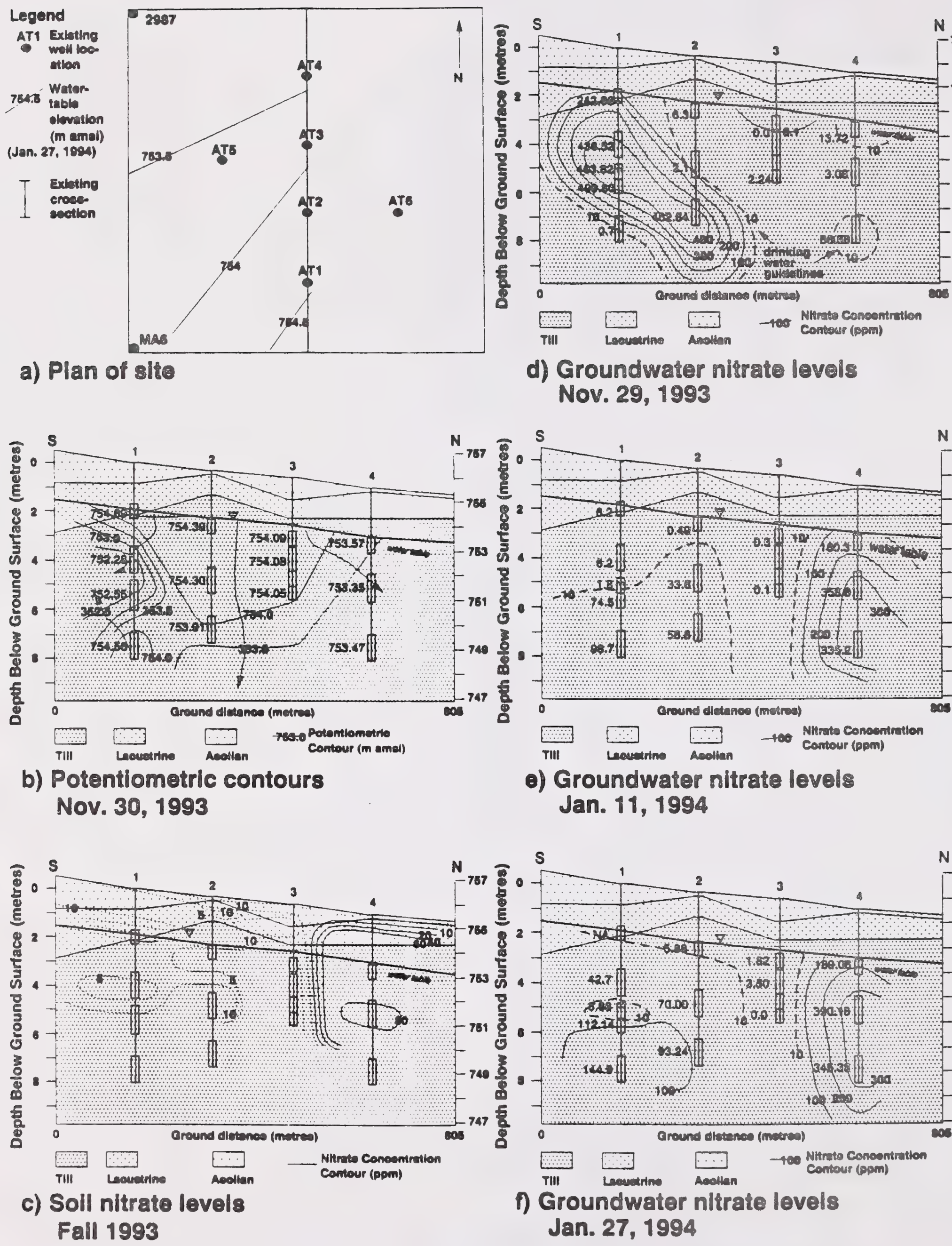


Figure 3. Soil and groundwater information for site 1.

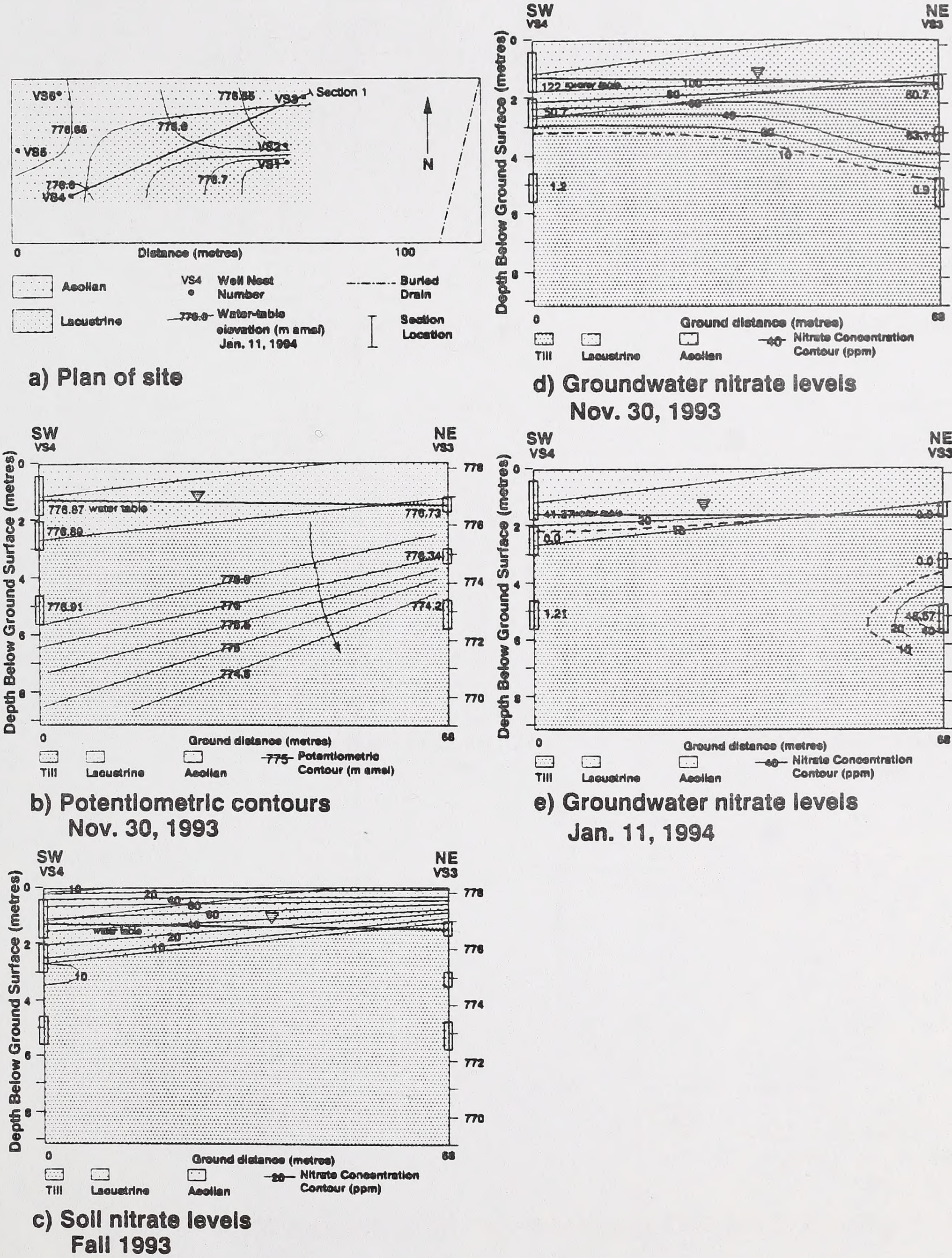
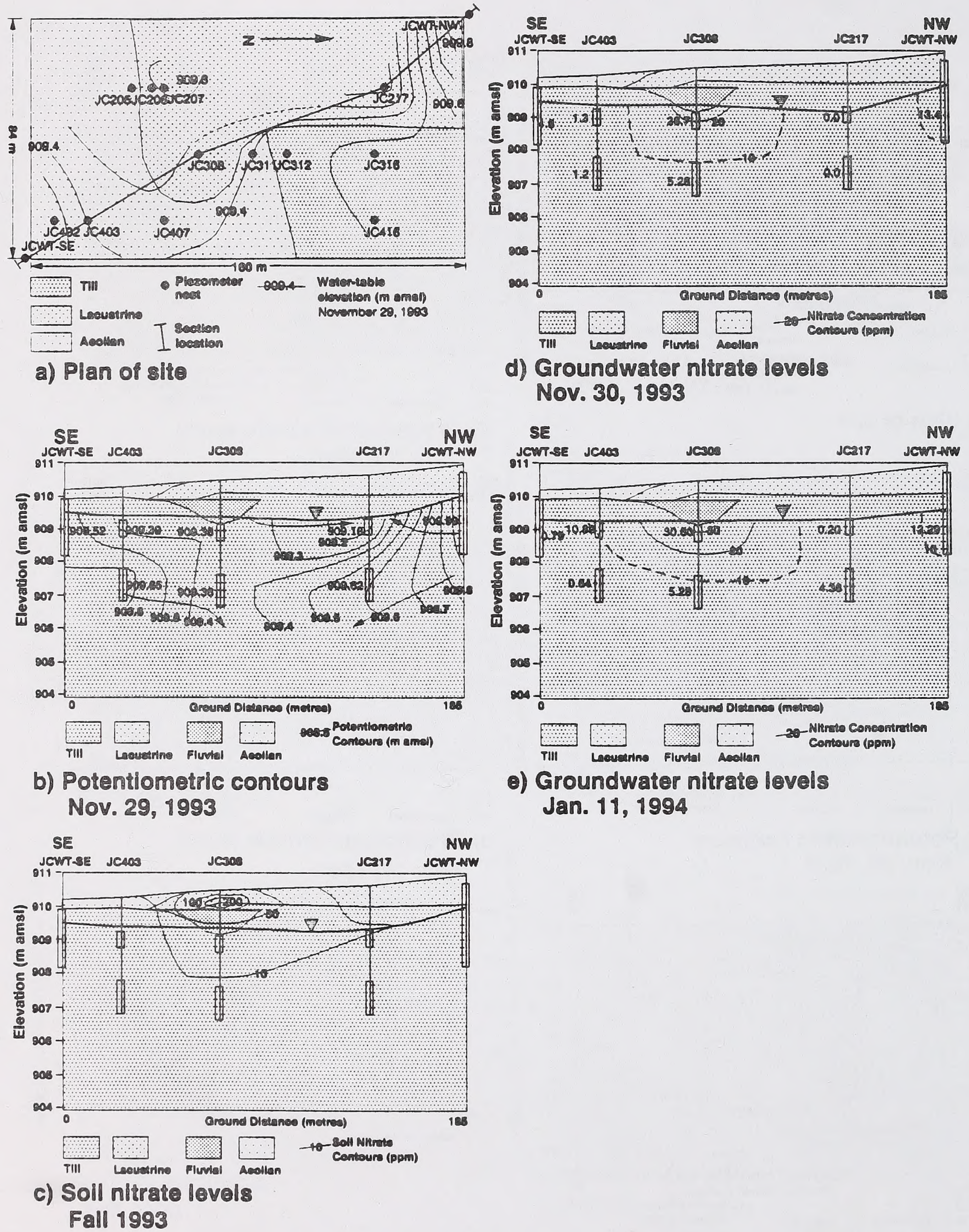


Figure 4. Soil and groundwater information for site 2.



a) Plan of site

b) Potentiometric contours
Nov. 29, 1993

c) Soil nitrate levels
Fall 1993

d) Groundwater nitrate levels
Nov. 30, 1993

e) Groundwater nitrate levels
Jan. 11, 1994

Figure 5. Soil and groundwater information for site 3.